Volume 14 MAY 1930 Number 5

# BULLETIN
*of the*
# American Association of Petroleum Geologists

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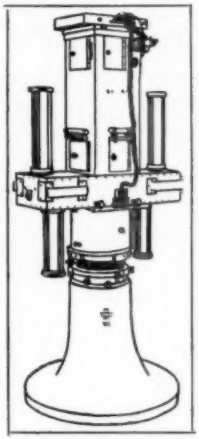

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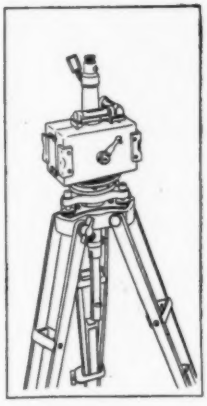

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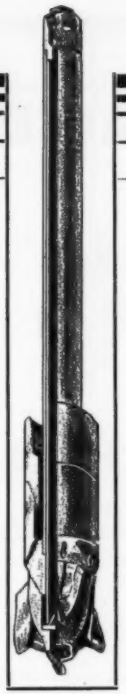

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|---|---|---|---|---|---|---|---|---|
| Blank No. 1 | 1,864-2,674<br>810 feet | 15 | 17 | 38 min. | $21.53 | 8—9⅞″<br>4—6⅛″ | 81.0′<br>49.0′ | 5 |
| Blank No. 2 | 1,154-3,553<br>2,365 feet | 42 | 55 | 44 min. | 23.06 | 21—9⅞″<br>16—6⅛″ | 59.6′<br>69.5′ | 12 |
| Blank No. 11 | 3,151-5,575<br>2,424 feet | 70 | 50 | 52 min. | 28.89 | 25—9⅞″<br>22—6⅛″ | 52.0′<br>50.0′ | 15 |
| Blank No. 7 | 4,678-5,594<br>916 feet | 56 | 19 | 85 min. | 29.52 | 34—9⅞″<br>6—6⅛″ | 22.9′<br>23.0′ | 5 |
| Blank No. 25 | 3,005-4,591<br>1,465 feet | 33 | 27 | 90 min. | 22.00 | 23—6⅛″ | 63.3′ | 8 |
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| Blank No. 93 | 2,809-2,960<br>151 feet | 16 | 7 | 32 min. | 23.56 | 2—8¾″ | 25.5′ | 2 |
| Blank No. 2 | 3,338-5,617<br>2,279 feet | 80 | 118 | 65 min. | 27.00 | 22—9⅞″<br>32—6⅛″ | 60.0′<br>43.6′ | 31 |
| Blank No. 1 | 2,260-5,770<br>3,510 feet | 97 | 54 | 59 min. | 21.55 | 59—9⅞″<br>3—6⅛″ | 54.0′<br>103.0′ | 17 |
| Blank No. 1 | 2,851-3,925<br>1,074 feet | 38 | 32 | 50 min. | 25.91 | 12—9⅞″<br>6—6⅛″ | 66.2′<br>30.0′ | 9 |
| TOTAL, 10 Wells | 15,327 feet | 462 | 388 | 65.5 m. | 24.70 | 181—9⅞″<br>2—8¾″<br>117—6⅛″ | 56.6′<br>25.5′<br>54.2′ | 106 |

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*of the*

# AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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Volume 14 Number 5

BULLETIN

*of the*

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

MAY 1930

# DETERMINATION OF GEOTHERMAL GRADIENTS IN OKLAHOMA[1]

JOHN A. McCUTCHIN[2]
Norman, Oklahoma

## ABSTRACT

The American Petroleum Institute is carrying on an extensive investigation of the geothermal gradients in the oil fields of California, Texas, and Oklahoma, the purpose of which is to determine the possibility of using temperature data for the location of future oil pools.

Temperature surveys have been made in approximately one hundred fifty wells located in twenty-four separated fields. As a whole, these data seem to indicate that the isothermal surfaces are related to the proved anticlines and oil-bearing areas and to the regional dip of the geologic formations across the state. The variations within the individual fields are ordinarily small but measurable and uniform, although the variations from area to area are large. This paper is concerned with the data collected in Oklahoma and the conclusions therefrom.

## INTRODUCTION

The American Petroleum Institute, with the aid of funds donated by John D. Rockefeller, has been carrying on this work as a full time project since June 1, 1928. During this time approximately one hun-

[1]Read before the Association at the New Orleans meeting, March 21, 1930. Manuscript received by the editor, February 22, 1930.

This paper contains preliminary results obtained in an investigation on the determination of geothermal gradients in oil fields located on anticlinal structures in Oklahoma, listed as Project 25-A of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by John D. Rockefeller. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council.

[2]American Petroleum Institute research fellow.

dred fifty wells located in twenty-four fields in Oklahoma have been tested. The writer wishes to thank the members of the Central Petroleum Committee and of the National Research Council for permission to publish this progress report. He is also indebted to Charles N. Gould,[1] director of the project in Oklahoma, for assistance, supervision, and direction; and to C. E. Van Orstrand for valuable suggestions in the collection of data and interpretations of results.

## DESCRIPTION OF METHODS AND APPARATUS

The "Van Orstrand method" of measuring temperatures in deep wells, developed and used successfully for 10 years by C. E. Van Orstrand of the United States Geological Survey, has been closely followed in the collection of these data. This method involves the lowering of thermometers, by means of piano wire, into the wells, and taking readings at 250-foot intervals. Although a detailed description of this apparatus and method has been published,[2] a summary of the method is given here for the convenience of the reader.

The thermometers used are mercury-in-glass thermometers of the maximum type, specially constructed with very small constrictions so that they will not be shaken down easily when being retrieved from great depths. Three thermometers in a single container are lowered to each point where an observation is to be made and the average reading of the three is taken as the temperature of the rocks at that point. Each set of thermometers is so selected as to include one thermometer which is much more difficult to shake down than the other two, in order to guard against inaccurate observations caused by the thermometers being shaken down as they are withdrawn from the well. If the thermometers receive excessive bumps while coming out of the well, the one with the smaller constriction will remain up and show a higher temperature than the other two, and the reading must be duplicated.

Each well is tested as though a laboratory experiment were being carried out and no effort is spared to make the observations highly accurate. The thermometers are constructed accurate to 0.2° F. and are read to 0.1° by means of a thermometer-reading telescope. At least one new thermometer is run with each set of three in order to insure against the low and inaccurate readings shown by thermometers which have been in use for some time, and when any thermometer is observed

[1] Director, Project 25-A.

[2] C. E. Van Orstrand, "Apparatus for the Measurement of Temperatures in Deep Wells by Means of Maximum Thermometers," *Econ. Geol.*, Vol. 19 (1924), pp. 229-48.

to read as much as 0.3° low, consistently, it is discarded. The depth-temperature curve is plotted in the field on a large scale for each well, and when any observation is seen to fall off the smooth curve, the reading is duplicated. With this type of apparatus it is believed that an accuracy within 0.2°-0.3° F. can be maintained.

The machine used to lower the thermometers into the well is hand operated. It consists of a steel frame and measuring wheel which accurately records the depth in feet. A reel about a foot in diameter and 3 inches across the face is provided for spooling the piano wire. The reel is equipped with two handles for winding the thermometers out of the well, and a brake to facilitate lowering them into the well. The machine proper is mounted on a four-legged stand and guyed to the derrick floor by means of turnbuckles to prevent vibration as the thermometers are raised and lowered. The total weight of this machine, including 6,000 feet of piano wire, is approximately 75 pounds.

The thermometers are enclosed in perforated brass tubes for readings which are taken in air, and are left suspended for an hour and a quarter at each point where an observation is made. For readings to be taken below the fluid level in a well, the thermometers are placed in sealed steel tubes which protect them from the fluid pressure, and are left suspended in the fluid 45 minutes. Observations are made at 100 feet and every 250 feet thereafter nearly to the bottom of the well, thus obtaining a temperature survey of each well. This type of apparatus is satisfactory for measuring temperatures in wells down to depths of approximately 4,500 feet if the wells are straight and the casing free from foreign material, but is not well adapted to measuring temperatures in wells which are crooked or have considerable paraffine, scale, or heavy rotary mud inside the casing. The average time for completing a 3,000-foot test is a day and a half.

Where a temperature of 60° F. is found at 100 feet and a temperature of 100° F. at 1,500 feet, as is the condition in many wells, it might be expected that circulation of the air and fluid inside the casing would seriously affect the temperatures at the shallower depths, but observations indicate that this is not the fact.

If any appreciable circulation takes place in a well, it seems reasonable to expect that the circulation in the air will be different from that in the fluid, and that the observations made immediately above the fluid level will not align well with those made in the fluid. If the well is not making gas, it is impossible to locate the fluid level by examining the depth-temperature curve. Nevertheless, if the well is

making only a very small amount of gas either around the casing or through it, the fluid level is easily located by noticing the sharp bend in the depth-temperature curve as it passes from the part of the well containing fluid to that part containing air. These observations indicate that it is not necessary to use any apparatus either above or below the thermometer containers to prevent circulation in the well.

### WELLS SUITABLE FOR TEMPERATURE TESTS

One of the chief difficulties of the problem in Oklahoma has been the location and availability of wells which are suited for temperature tests. As a rule, the wells which have been drilled with rotary tools are the most unsatisfactory wells in which to make temperature observations. The circulation of the rotary mud in the wells so disturbs the temperature distribution in the formations surrounding the hole that the well must remain idle for a considerable time before reliable temperature data can be obtained, the length of time depending principally upon the length of time the rotary mud has been circulated. In the Oklahoma City field, where the drilling time is approximately 125 days, a well which had been idle 30 days was found to be in temperature equilibrium, although one well was tested which had been idle 24 days and yet was out of temperature equilibrium. The period of 10 days allowed for running the casing and giving the cement time to set is not sufficient for the wells which have been drilled with rotary tools to return to temperature equilibrium. Wells which are making even a small amount of gas either through the casing or around it, wells which have been swabbed recently, or have pumped large quantities of fluid recently, also are not suitable wells in which to make temperature observations.

Temperature tests may be made in wells drilled with standard tools at any time the tools are out of the well. Temperature observations should not be made near the bottom of drilling wells, because the action of the drill may produce an abnormally high temperature at this point. Nothing significant or important is to be gained by bottom-hole temperatures. When a temperature survey of the well has been made, including readings every 250 feet in the well from the top to a depth within 100 feet of the bottom, it is easy to estimate the temperature at the bottom within 0.5° F. Any well more than 1,000 feet deep which has been temporarily abandoned and is not making casinghead gas, or any drilling well where the standard-tool method of drilling is being used, is ordinarily a reliable source of temperature data.

An attempt was made to take temperature observations in 2-inch core-drill holes in Jefferson County, Oklahoma. The thermometers were run into the well immediately after the core-drill rods had been withdrawn, but due to the circulation of the mud during drilling, the holes were not in temperature equilibrium. Several holes were visited after they had been idle 7 days, but were found to have caved in. This suggests that if temperature observations are to be made in core-drill holes in soft, unconsolidated sediments, the holes will have to be tubed. With the present type of apparatus 1½-inch tubing would suffice.

## DEPTH-TEMPERATURE CURVES

Figure 1 shows a depth-temperature curve taken from a deep well in the Tonkawa field. Depth-temperature curves representing wells which are in temperature equilibrium may, for all practical purposes, be considered as straight lines. However, when a close examination is

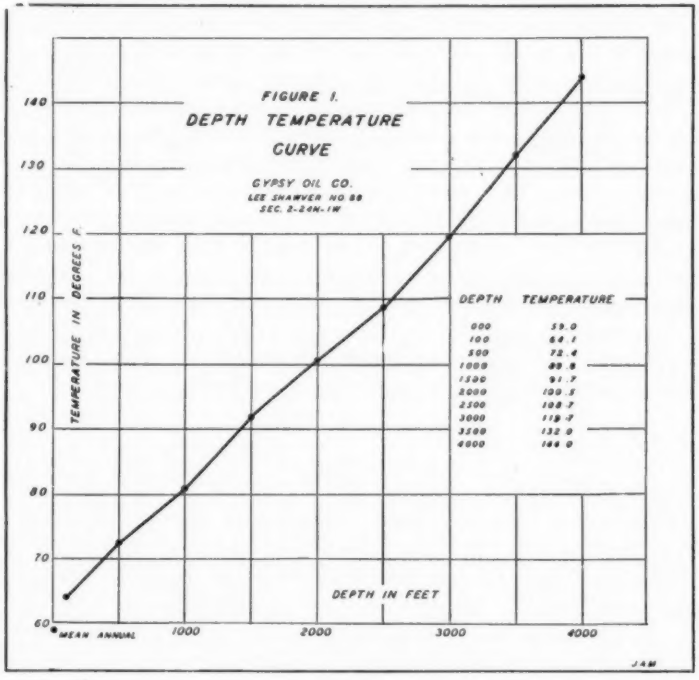


FIG. 1

made, the curves are seen to be slightly curved at the shallower depths, the curvature increasing with increasing depth. In general, the curves from all fields where tests have been made except the curves from the El Dorado and the Florence fields in Kansas, have shown this tendency. The curves from these fields are the only curves which have shown a decreasing slope increasing with depth. This suggests that the underlying granite ridge, which is known to exist beneath these fields at shallow depths, has affected the temperature distribution in the overlying rocks and has caused this exceptional type of depth-temperature curve.

When depth-temperature curves are extended back to the temperature axis, that is, the surface of the ground, they are seen to intersect this axis slightly above the mean annual air temperature of the area where the well is located, the mean annual air temperature being interpolated between the nearest United States Weather Bureau stations. For wells located in Oklahoma and Kansas this excess of soil temperature over air temperature varies from 1° to 4° F. A depth-temperature curve indicating an excess of soil temperature over air temperature of more than 4° is an excellent indication that the well is not in temperature equilibrium; therefore, the data from the well should be questioned.

The depth-temperature curves made for some fields have shown a slight irregularity at a certain depth. The fact that all the curves taken from these fields show that tendency indicates that it is a real reflection of an exceptional heat distribution rather than the result of errors of observation. Accordingly, the logs of several wells were examined and it was found that a water sand was recorded in some wells at approximately this depth, and in others a showing of gas was reported. Several wells were investigated where the log failed to indicate the explanation for the irregularity. It is believed that considerable valuable information is forthcoming when all the depth-temperature curves which are now available are plotted alongside of the logs of the wells.

### SHALLOW TEMPERATURES

By far the most important temperature data in a well are to be obtained from the first 1,000 feet. If the well is out of temperature equilibrium in any way, the shallow temperatures reflect it to a larger extent than the deeper temperatures. The lowest temperature in a well is to be found near the 100-foot point and is not materially changed from season to season during the year. If any circulation caused by gas or by operating conditions has taken place in the well recently, the shallow temperatures are too high, bringing the upper part of the depth-tem-

perature curve much above what it should be. Since the shallow temperatures act as a guide to the reliability of the data from the entire well, they should be given careful consideration by anyone endeavoring to correlate temperature data from well to well or area to area. The temperature at 100 feet is dependent directly on the mean annual air temperature of the area where the well is located, and corrections should be made for this condition if comparisons are made between areas differing in mean annual air temperature.

### EXPLANATION OF CROSS SECTIONS

### (FIGURES 2 AND 3)

Figure 2 shows the variation in depth to the 80°, 90°, and 100° F. isothermal surfaces from a point between Sapulpa and Tulsa, to Cromwell-Franklin's Thompson No. 1 well, located just north of Oklahoma City. Figure 3 shows a similar cross section except that the line of the cross section in this figure is taken more nearly at right angles to the strike of the formations. Figure 8 shows the location of the fields in which tests have been made in Oklahoma. The line *A-A* in Figure 8 represents the line of the cross section appearing in Figure 2 and the line *B-B* represents the line of cross section appearing in Figure 3. The broken line in Figure 8 is the general regional strike of the formations in this section of Oklahoma based on the Belle City-Dewey limestone outcrops.

Two rather significant facts are suggested by these cross sections. The isothermal surfaces dip rapidly and uniformly toward the west, and converge toward the east in this section of Oklahoma. The 100° isothermal surface is only approximately 1,500 feet deep near Tulsa, although this surface is more than 4,000 feet deep near Oklahoma City. The 80° isothermal surface is only about 750 feet from the 100° surface near Tulsa, whereas it is more than 2,000 feet above this same surface in the Oklahoma City well.

The cross section shown in Figure 3 is taken more nearly at right angles to the strike of the formations, and the isothermal surfaces dip more uniformly in this cross section than they do in Figure 2. So far as temperature data have been obtained in Oklahoma to date, the farther east and northeast a well is located, the higher the temperature at any depth, and the nearer the surface of the ground the isothermal surfaces are found. The depths to the isothermal surfaces appearing in Figures 2 and 3 are influenced to some extent by the variations within the in-

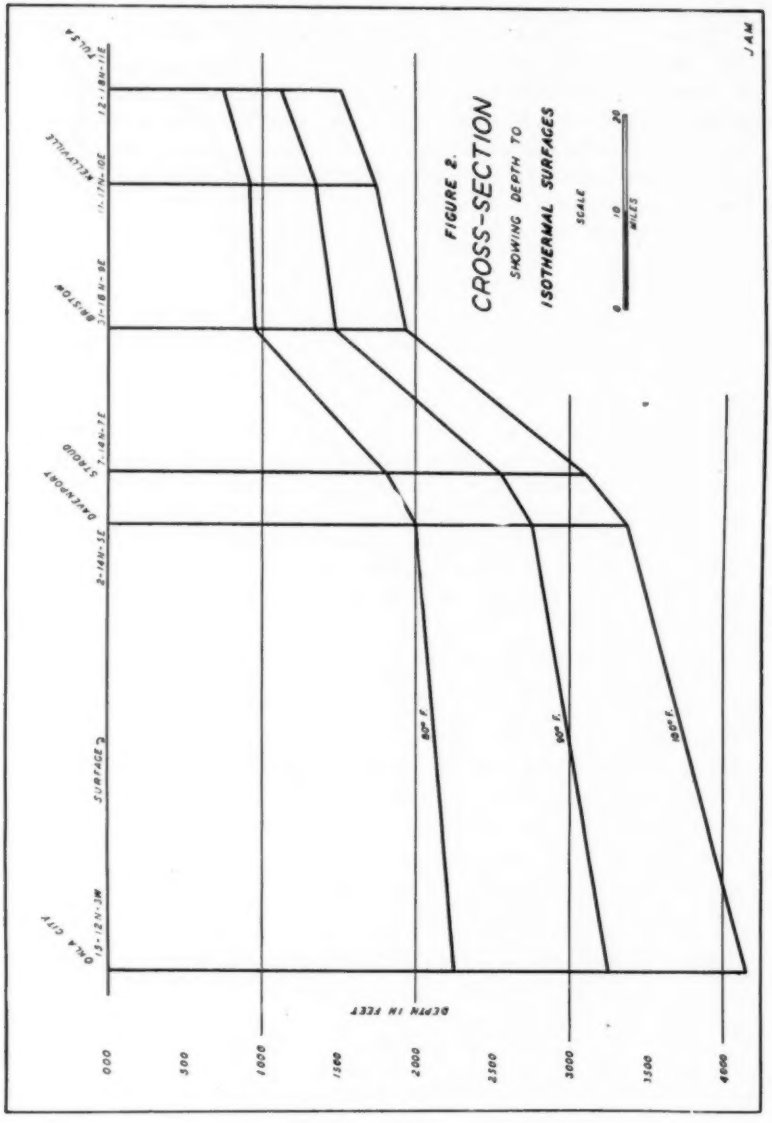
FIGURE 2.
CROSS-SECTION
SHOWING DEPTH TO
ISOTHERMAL SURFACES
SCALE
0
10
20
MILES
JAM
POLK
KELLYVILLE
BRISTOW
STROUD
OAKLEYNOOKY
OKLA CITY
SURFACE
80° F.
90° F.
100° F.
DEPTH IN FEET
000
500
1000
1500
2000
2500
3000
3500
4000

FIG. 2

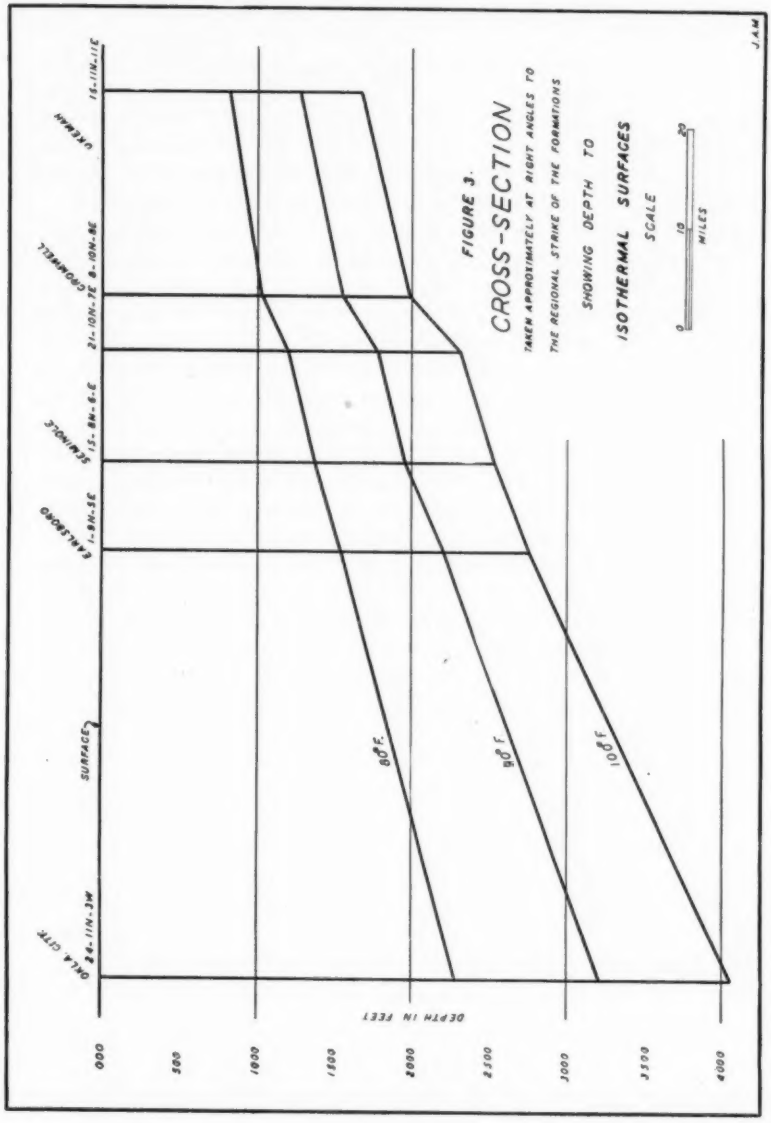
FIGURE 3.
CROSS-SECTION
TAKEN APPROXIMATELY AT RIGHT ANGLES TO THE REGIONAL STRIKE OF THE FORMATIONS
SHOWING DEPTH TO
ISOTHERMAL SURFACES
SCALE
0
10
20
MILES
OKLA CITY
24-11N-3W
SURFACE
EARLSBORO
35-9N-5E
SEMINOLE
15-8N-6E
CROMWELL
21-10N-7E
8-10N-8E
OKEMAH
15-11N-11E
80°F.
90°F
100°F
DEPTH IN FEET
000
500
1000
1500
2000
2500
3000
3500
4000

FIG. 3

dividual fields, which may account for the irregularity of the depths to these surfaces.

It is considered rather remarkable that the regional dip of the formations in this area so closely parallels the dip of the 100° isothermal surface. The gradient varies from 1° in 107.0 feet for the wells located near Oklahoma City, to 1° in 36.5 and 40.0 feet for wells located near Tulsa and Okemah. This variation is so pronounced that core-drill holes 1,500 feet deep across the area would have clearly indicated it.

As to the reason for this variation, several possibilities are suggested. It is generally agreed that the sediments of northeastern Oklahoma have been more deeply buried, consequently are now more compact and have a higher density than the sediments now found at the same depths farther west. It is also known that the depth to the pre-Cambrian granite is much less in the northeastern part of Oklahoma than it is in the central part. It has been suggested that perhaps the rocks, having different rates of heat conduction parallel with the bedding rather than across it, now manifest that property in the present heat distribution. Chemical reaction and the circulation of ground water through the gently tilted sediments have their possibilities and should be given consideration.

The fact that the depth-temperature curves for the wells indicate that the average surface temperature of soil is always 2°-4° F. higher than the mean annual air temperatures should have a rather significant bearing on any explanation which is selected. If the mean annual air temperature is lower than the mean annual soil temperature, there will be a heat flow from the soil into the atmosphere, which indicates that the earth's internal heat is in a kinetic state and not a static state, and that there is a heat flow from every point of higher temperature within the earth to some adjacent point of lower temperature. Any reason or group of reasons chosen to explain these variations should incorporate the foregoing indication.

More time has been spent in the collection of accurate data on this problem in Oklahoma up to the present than has been devoted to seeking an explanation for the various suggestions which these data seem to offer. The writer does not consider that enough data have been collected to permit a very reliable or probable explanation at present.

### EXPLANATION OF TABLE I

Table 1 shows the variations in the gradients, computed in terms of feet per degree F., for the fields where tests have been made. As a rule, the higher gradients are obtained from wells located near the edges of

the fields and the lower gradients from wells located near the centers of the fields. It is to be understood that the larger the gradient in feet per degree, the lower the temperature at any depth in a well.

TABLE I

| *Field* | *Number of Wells Tested* | *Maximum Value of Gradient* | *Minimum Value of Gradient* | *Average Value of Gradient* |
|---|---|---|---|---|
| Healdton | 4 | 149.0 | 79.2 | 116.6 |
| Seminole | 10 | 80.4 | 55.5 | 64.5 |
| Wewoka | 3 | 48.9 | 47.5 | 48.2 |
| Cromwell | 10 | 58.7 | 47.5 | 47.8 |
| El Dorado, Kan. | 20 | 57.5 | 47.7 | 51.0 |
| Tonkawa | 11 | 54.3 | 49.5 | 51.8 |
| Walters | 4 | 121.5 | 110.2 | 114.3 |
| Okemah | 4 | 44.6 | 39.2 | 42.4 |
| Glenn Pool | 19 | 43.9 | 36.5 | 39.8 |
| Papoose | 4 | 49.7 | 43.6 | 45.9 |
| Sasakwa | 1 | 65.8 | 65.8 | 65.8 |
| Slick | 5 | 47.5 | 39.8 | 43.7 |
| Wetumka | 1 | 44.0 | 44.0 | 44.0 |
| Kellyville | 1 | 41.2 | 41.2 | 41.2 |
| Josey | 1 | 42.7 | 42.7 | 42.7 |
| Bristow | 2 | 44.7 | 44.4 | 44.5 |
| Key West | 4 | 69.2 | 66.0 | 67.4 |
| Drumright | 11 | 67.0 | 45.7 | 53.4 |
| Florence, Kan. | 8 | 66.3 | 58.4 | 62.9 |
| Garnett, Kan. | 4 | 61.5 | 40.4 | 51.2 |
| Garber | 5 | 64.0 | 52.6 | 57.9 |
| Billings | 3 | 56.6 | 47.3 | 52.5 |
| Burbank | 8 | 50.0 | 45.0 | 47.5 |
| Oklahoma City | 3 | 110.6 | 102.7 | 106.9 |
| Davenport | 3 | 93.8 | 73.6 | 82.4 |

EXPLANATION OF FIGURE 4

The solid contours show the structure of the Garber field as revealed by drilling to the Layton sand contoured on a 50-foot interval. The broken lines are drawn on the 80° F. isothermal surface; a 25-foot interval is used. The wells which have been tested are plotted with their assigned numbers above the well locations and the depths to the 80° isothermal surface at the right of the well locations.

Although only four good tests were made in this field, they were well located with respect to the structure and show that the isothermal surfaces could be used to outline the general trend of the structure. It is to be noticed that the Layton sand is approximately 3,600 feet deep in this field and that the 80° isothermal surface is only approximately 1,000 feet deep. The closure is much more on the Layton sand than on the 80°

isothermal surface, but had the 100° isothermal surface been chosen, this surface would coincide more nearly than the shallower 80° surface does.

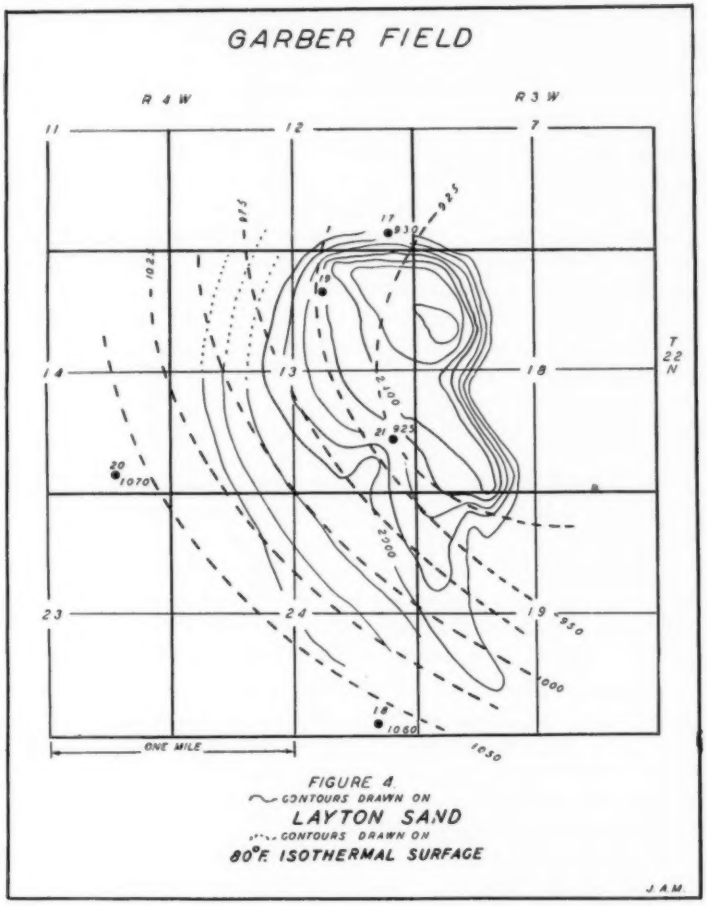


FIG. 4*

*As a result of imperfect notations on the original drawing, two incorrect numbers appear in Figure 4. In the upper right corner of the central square "2100" should be *2400;* in the square below, "2000" should be *2600.*

EXPLANATION OF FIGURE 5

The solid contours shown in Figure 5 are drawn on top of the Cromwell sand by the use of a 40-foot interval and are taken from the U. S. Bureau of Mines report on that field.[1] The broken contours are drawn on top of the 100° F. isothermal surface, a 20-foot contour interval being used. The structural difference in wells tested is about 150 feet and the difference in the depth to the 100° isothermal surface is about 100 feet. An interesting suggestion is presented by comparing the depth to the

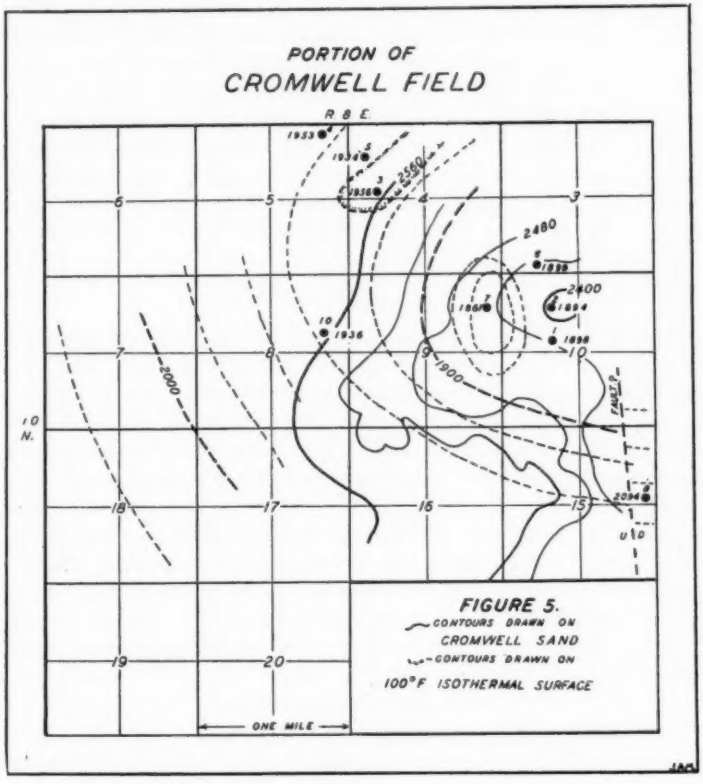


FIG. 5

[1] C. O. Risen and John R. Bunn, "Petroleum Engineering in the Cromwell Oil Field," *U. S. Bur. Mines Rept.* (December 1, 1924).

isothermal surface in the well located in Sec. 9, T. 10 N., R. 8 E. with the depth to the same surface in the well located in Sec. 15, T. 10 N., R. 8 E. Risen and Bunn, in their report, suggested the presence of a fault with 200 feet displacement striking west of north and passing through the east half of Sec. 15, T. 10 N., R. 8 E. The difference in the depth to the 100° isothermal surface in the two wells is about 230 feet. This is the only evidence on record on this problem relating to faults in Oklahoma and their influence on the temperature distribution in the adjacent rocks.

An isolated well, not shown in Figure 5 but located approximately 5 miles southwest of the west edge of the area mapped, showed a markedly lower temperature than wells located in the Cromwell field proper. Whether the small bubbles of gas which came out of the casing at intervals caused enough circulation in the fluid to raise the value of the gradient from about 1° F. in 47.8 feet (the average for wells located within the field) to 1° in 58.8 feet (the gradient in this well) is a question which can not be answered until more data are collected under more nearly ideal conditions. The depth-temperature curve for this well indicates that it is in temperature equilibrium.

### EXPLANATION OF FIGURE 6

Figure 6 shows the location, the depth to 100° F., and the gradient for three wells located on the Haverhill, Kansas, sand lens. The dotted line represents the approximate limit of the productive part of the lens. Wells 32 and 33 were tested when the casing was being cemented, and although they had been idle only 3 days, they were found to be in temperature equilibrium. All three of the wells were drilled with standard tools. Only a showing of gas was encountered in well 31, although wells 32 and 33 were later drilled down and made good producers. The 100° F. isothermal surface is seen to drop about 100 feet from the producing wells to the dry hole, though the values of the gradients are a little less for the producing wells than for the dry hole. This information supports the less reliable indications obtained from the Glenn pool, Oklahoma.

### EXPLANATION OF FIGURE 7

The structural contours shown by the solid lines in Figure 7, taken from the *Kansas Geological Survey Bulletin 7*, are drawn on top of the Fort Riley limestone, which is the formation exposed in the area. In general, the surface structure of the field agrees with the subsurface structure, the main difference being that the subsurface dips are steeper.

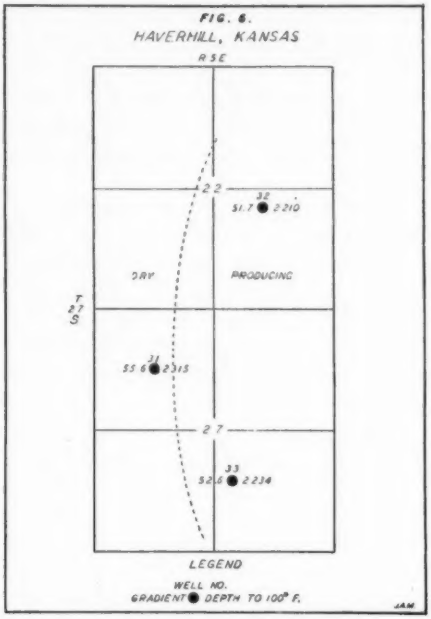


FIG. 6

This field is located on what has been termed a "buried granite ridge" which extends intermittently from southern Nebraska across Kansas and has been traced into northern Oklahoma. The depth to the granite in the shallowest part of the field is about 3,000 feet. The broken contours are drawn on the 100° F. isothermal surface, a 50-foot contour interval being used.

Figure 7 indicates a marked agreement of temperature variation with geologic structure in the El Dorado, Kansas, field, the geothermal "highs" occurring slightly west of the structural "highs." It should also be noticed that the geothermal "highs" coincide with the most prolific areas. More data in this area might bring isothermal "highs" closer to the crests of the domes. The isothermal surfaces in this field show steeper dips than do the geologic structures.

### VARIATIONS IN OKLAHOMA AND KANSAS FIELDS

Temperature observations have been made in twenty-four fields in Oklahoma and Kansas. Because the only wells that were available for

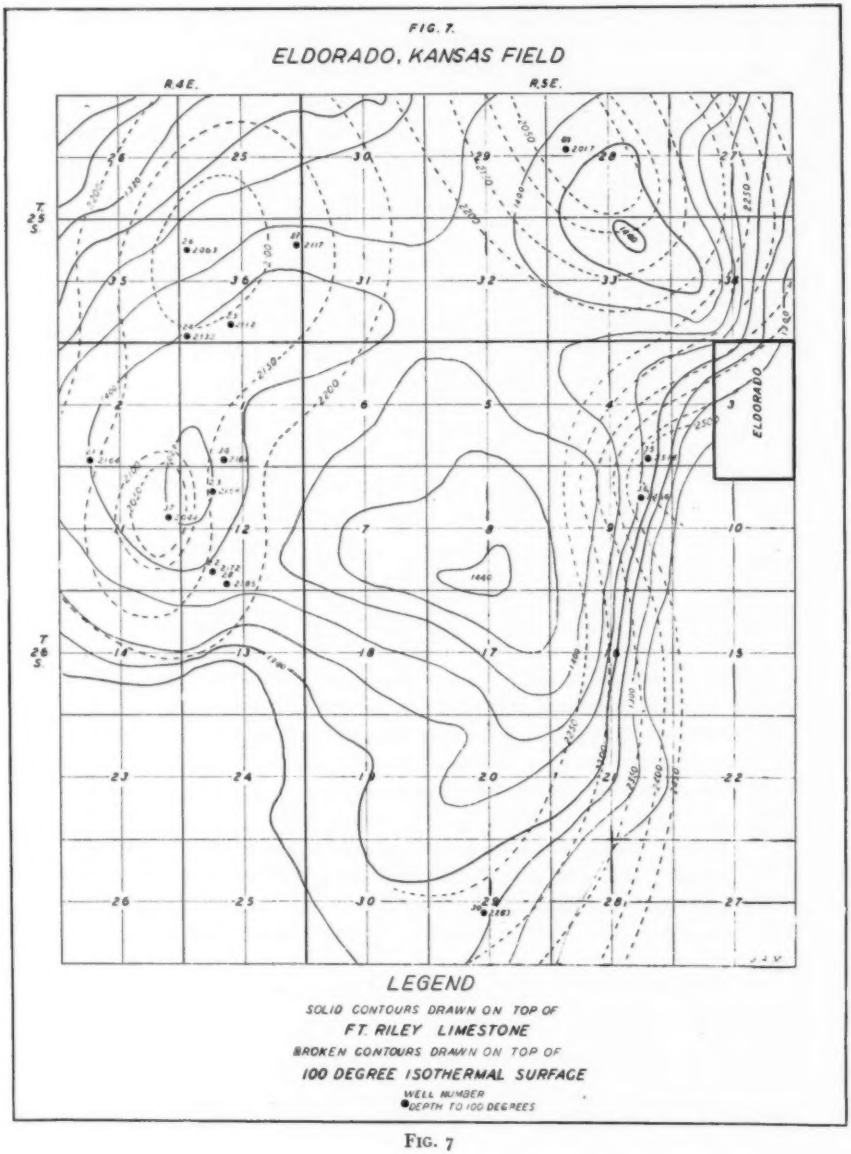
FIG. 7.
ELDORADO, KANSAS FIELD
R.4E.
R.5E.
T. 25 S.
T. 26 S.
ELDORADO
LEGEND
SOLID CONTOURS DRAWN ON TOP OF
FT. RILEY LIMESTONE
BROKEN CONTOURS DRAWN ON TOP OF
100 DEGREE ISOTHERMAL SURFACE
WELL NUMBER
DEPTH TO 100 DEGREES

FIG. 7

testing happened to be temporarily abandoned at the time the fields were visited, the data from most of these fields are too meager to permit conclusions to be drawn regarding the variation of temperatures with geologic structures. However, it is interesting to notice that in only two or perhaps three fields have the data collected tended to disagree with the findings of Van Orstrand's previous work in the Wyoming and California fields.[1]

One well tested near the edge of the Wewoka, Oklahoma, field showed a slightly higher temperature at certain depths than a well which was located near the center of the field and structurally higher. It is possible that when more wells are tested in this field, the result will show that one or both of these wells might have been out of temperature equilibrium in some way or that the holes were so crooked as to permit an error in the vertical depth sufficiently large to overcome the indicated anomaly in the depths to the isothermal surfaces. Only two wells were available for testing when the field was visited, and more than two wells in a field are necessary before a conclusive decision can be made regarding the variation.

The data collected from eleven wells in the Tonkawa, Oklahoma, field also failed to show an agreement of temperature variation with geologic structure. This field produces oil and gas from four sands, and the wells are located four to the location. Considerable casinghead gas is taken from the wells and considerable fluid pumped from the several producing sands every day. This might be a contributing factor in explaining the fact that the geologic structures do not coincide to any great extent with the temperature variations in this field. It was of interest to observe that the depth-temperature curves showed no deviation from the normal at the depths corresponding with the position of the producing horizons. This indicates either that the oil-bearing strata do not have higher temperatures than the adjoining rocks, or that the circulation of the fluid and gas here has obliterated the traces. It has been suggested that the temperature in the wells tested at Tonkawa reflect a structure at a greater depth than has been revealed as yet by the drill, that perhaps there is an uplift in the Arbuckle limestone which is not reflected in the structure of the "Wilcox" sand.[2] In general, the data collected at Tonkawa illustrates the importance of collecting temperature data before the fields have produced oil and gas.

[1]C. E. Van Orstrand, "Some Evidence on the Variation of Temperatures with Geologic Structure in Wyoming and California Fields," *Econ. Geol.*, Vol. 21, No. 2 (March-April, 1926), pp. 145-65.

[2]K. C. Heald, "Determination of Geothermal Gradients," *Oil and Gas Jour.* (December 5, 1929).

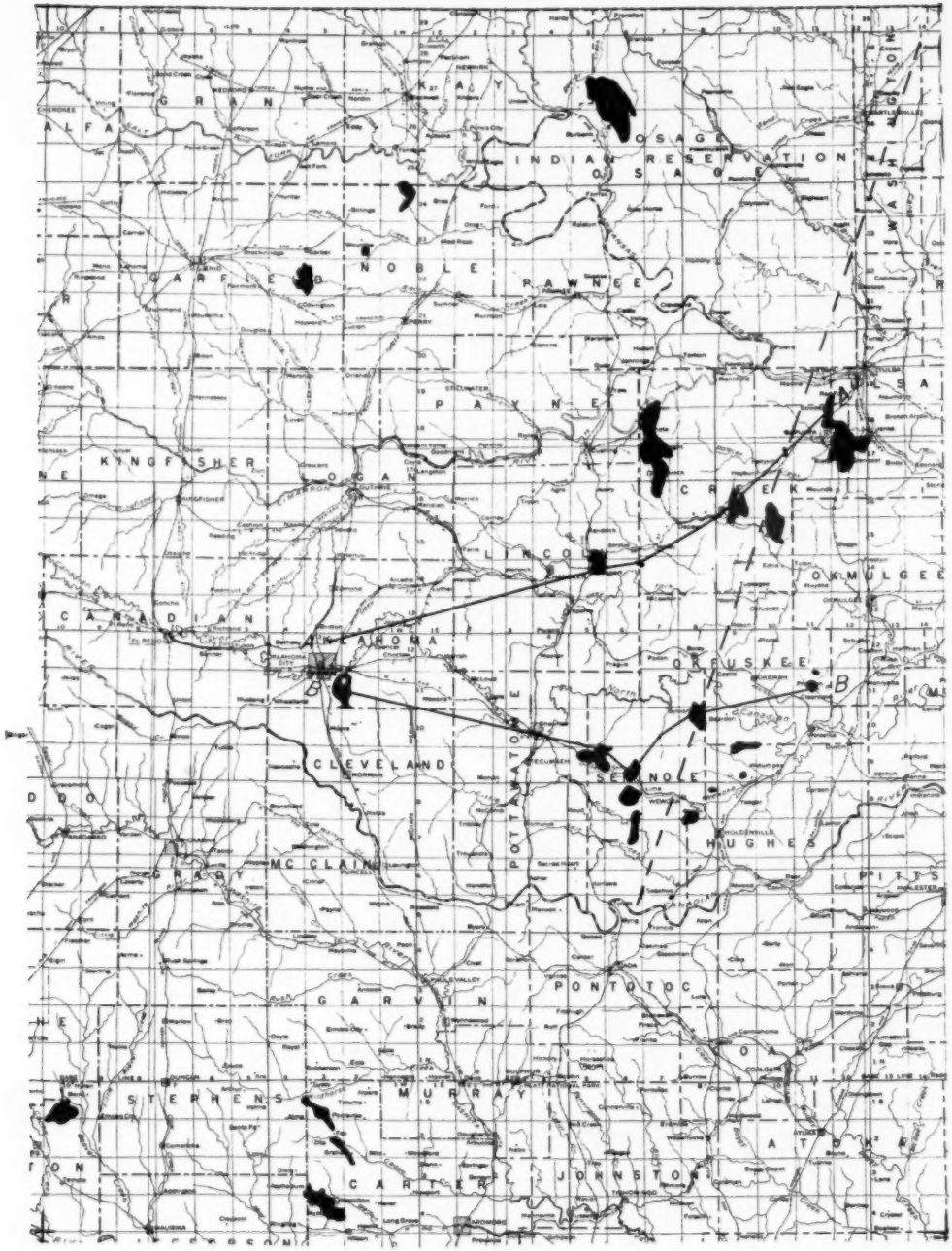


FIG. 8.—Map of a part of Oklahoma showing the location of fields where tests have been made. The solid lines *A-A* and *B-B* are the lines of cross section of Figures 2 and 3. The dotted line shows the regional strike of the geologic formations based upon the Dewey-Belle City limestone outcrops. Width of area of map, 144 miles. Base map from U. S. Geological Survey.

A dry hole located outside the field proper and a well located near the center of the Oklahoma City field showed approximately the same temperatures at corresponding depths from the top of the hole to the 4,000-foot level. This seeming exception to the general rule is of interest, as these observations were made before an appreciable amount of oil or gas had been produced from the field, and suggests the possibility that if the tests had been made in all the fields before they had produced any oil or gas, no variation would have been found.

In all the other fields where tests have been made, the structures are revealed to a larger or smaller degree. In the Cromwell, Garber, and El Dorado, Kansas, fields the temperature variations are seen to define the geologic structures fairly well.

### OTHER USES FOR TEMPERATURE DATA

Petroleum engineers of the major oil companies are finding new and important uses for the accurate temperature data which are being collected in Oklahoma. Recently a well in the Oklahoma City field was allowed to blow open, producing 60,000,000 cubic feet of wet gas and 1,000 barrels of gasoline. The State Corporation Commission wished to know whether this well was a gas well or an oil well according to the legal definition. Knowing the composition of the gasoline, the pressure at the casinghead, and the temperature at the bottom of the well, they were able to compute the quantity of gasoline which would remain in the liquid state under these conditions. It was decided that more than half the gasoline was liquid in the sand and that the remaining part was being made during the expansion of the gas in the gas trap.

Other engineers wish to know the temperature of the producing sand so that they may compute the volume which the injected gas will occupy when a re-pressuring program is to be started. In making acid-bottle tests for straightness of the hole, the viscosity and surface tension of the acid is dependent to a large extent upon the temperature. When the temperature is known, and a correction applied for it, more accurate angle readings can be made.

Certain designs of pumping equipment, particularly those using a steel plunger, are affected by the operating temperature. When the bottom-hole temperature is known, the necessary clearance may be more accurately determined, thus adding to the efficiency of the pump.

A rotary drilling contractor, drilling a well in Coal County, Oklahoma, found that at a depth of 7,100 feet the rotary mud became so hot as to cause serious warping of the mud-pump rubber valves. Had a

temperature survey of the first 1,000 feet of this well been made, or of a well located in this area, the temperature could have been accurately predicted and another type of valves could have been installed without loss of time.

## SUMMARY AND CONCLUSIONS

Although the data thus far collected on this problem in Oklahoma are by no means sufficiently complete to permit other than preliminary conclusions to be drawn, as a whole they do tend to support the general premise that the anticlines which have been productive of oil and gas have higher temperatures at specified depths than the areas surrounding these anticlines and productive areas.

The variations within the individual fields are ordinarily small but measurable and fairly uniform. The variations from area to area are large and seem to bear a relation to the regional dip of the formations. This latter variation is so pronounced that all the data as yet collected support it.

Due to the nature of the work, which involves the location and testing of idle wells, most of the data have been collected near and within the fields proper and very few tests have been made in dry holes located between the fields. This gives the problem a one-sided aspect, as it is impossible to know that geothermal anticlines do not exist where no true geological anticlines are to be found.

An interesting possible explanation for the variations within the individual fields is suggested by examining the available data. The anticlines which have been the most productive of fluid, either oil or water, show the largest and most uniform variations in temperatures at specified depths. It is possible, therefore, that the removal of large quantities of water and oil from the higher parts of the structures has permitted the warmer fluid from the greater depths, either down the dip of the formations or within the formations, to rise in the sands and occupy the pore spaces of the cooler rocks. It seems possible, therefore, that the abnormally high temperatures which are present now in the rocks over the anticlines may be due to this circulation, and that, if tests had been made in these wells before any fluid had been removed, no variations in temperature would have been found. This idea is supported by observations made in flowing wells where petroleum engineers have noticed that the temperature of the flowing oil increases with the age of the well. It is also supported by the fact that observations made in the Oklahoma City field before an appreciable amount of fluid had been removed from the field failed to show a marked variation in temperature with structure.

However, the tests which have been made in a few wells located in the non-productive areas indicate that these wells have rather markedly lower temperatures at specified depths as compared with the temperatures in wells located within the adjacent fields. In most places the data from the first 1,000 feet of the isolated well would have indicated an abnormally low temperature throughout the entire well.

As a whole, the results obtained in Oklahoma to date on this project are neither consistent nor inconsistent enough to justify any general conclusions as to the outcome of the project. The results do indicate that the problem is not simple and that it will probably be solved by the collection of additional, accurate data in the fields and in non-productive areas, supplemented, perhaps, by some careful work on the heat-conducting properties of sedimentary rocks in a well equipped laboratory. Particular attention should be given to the collection of data from fields which are being developed, so that more data will be available from areas where there is no possibility that the operating conditions have influenced them.

## DISCUSSION

W. T. THOM, JR., Princeton, New Jersey: It is indeed gratifying to learn from Mr. McCutchin's paper that his study of earth temperatures in Oklahoma wells has further demonstrated the practical utility of Van Orstrand's method of measuring earth temperatures, and has indicated a rise and convergence of isogeothermal surfaces above structural uplifts such as have been observed in western fields.[1]

It is greatly to be hoped that Mr. McCutchin's work, or a similar study, will be continued, as it obviously affords an indirect but nevertheless effective approach to many of our problems of earth deformation and of oil migration and accumulation, as well as to other problems of major geologic interest. Mr. McCutchin's work has evidently been done with great care and effectiveness, and is a contribution of real importance to our data of geophysics.

My single regret in connection with his report is that his cross sections (Figs. 2 and 3) do not show the position of key strata as well as the depth to particular isogeothermal surfaces, and that he apparently hesitated to undertake a more exhaustive analysis of the significance of the results described, and of the geologic factors probably entering into earth-temperature distribution. In view of the broad geologic interest of this study, an analysis[2] of the causes of variations in earth temperature gradients is here quoted.

[1]C. E. Van Orstrand, "Some Evidence on the Variation of Temperature with Geologic Structure in California and Wyoming Oil Districts," *Econ. Geol.*, Vol. 21 (1926), pp. 145-65.
W. T. Thom, Jr., "Relation of Earth Temperatures to Buried Hills and Anticlinal Folds," *Econ. Geol.*, Vol. 20 (1925), pp. 524-30

[2]W. T. Thom, Jr., "Inhomogeneities in the Earth or Atmosphere which May Cause Irregularities in Isogeothermal Surfaces in the Earth's Crust," unpublished manuscript submitted on February 28, 1929, at request of E. A. Eckhardt, for publication by the Division of Physical Science of the National Research Council.

INHOMOGENEITIES IN THE EARTH OR ATMOSPHERE WHICH MAY CAUSE IRREGULARITIES IN ISOGEOTHERMAL SURFACES IN THE EARTH'S CRUST

A. REGIONAL

1. *Distribution due to radioactive minerals.*—An irregular distribution of radioactive minerals in the earth must induce corresponding irregularities in local rates of heat evolution by radioactive disintegration.

2. *Irregularity of planetesimal or molecular condensation.*—Irregularities in the rates of planetesimal or molecular condensation within the earth also must induce corresponding irregularities in local rates of heat evolution.

3. *Subcrustal rock flowage.*—The subcrustal transfer of matter (by rock flowage) from beneath troughs of deposition to beneath near-by geanticlinal regions of denudation, induces frictional heating in the plastic rock. This process should induce arching of isothermal surfaces under the uplifted regions and a downwarping of the surfaces in the depression.

4. *Subaerial and submarine climatic differences.*—The notable differences in mean annual temperatures now existing between equatorial and polar regions and between continental and subsea or suboceanic areas, necessarily are reflected in local depth-temperature observations.

Moreover, past variation in geologic climate, in the distribution of land and water, and in atmospheric and oceanic circulation, introduce time as well as space factors into the relation between climatic and earth-temperature relations.

5. *Properties of different types of rocks.*—Different types of rocks are predominant in the outer crust of the different parts of the earth, certain regions being surfaced by a prevailing type of rocks,—basic, or acidic, or metamorphic, or sedimentary. These different types of rocks almost certainly have different heat conductivities. Consequently some regions may show characteristic variations from the average crustal temperature distribution.

6. *Tectonic deformation.*—The compressional deformation of the rocks of a region will necessarily subject them to frictional heating. Therefore dissimilarities in the time, or degree, of local tectonic deformations will produce corresponding differences in heat distribution in the crust.

Likewise, where radial movements have prevailed, the rocks of uplifted regions, being rendered more porous under release of pressure, may be less effective as heat conductors; whereas rocks undergoing downwarp and burial will be heated in consequence of the induced compression they must endure.

B. LOCAL

1. *Topographic relations.*—Rocks beneath a mountain range or ridge lose heat more rapidly than rocks beneath adjacent plains or valleys: (a) because subjected to a lower mean annual temperature; (b) because they possess a relatively greater radiating surface per unit of volume; (c) because chilling by downward meteoric circulation extends deeper beneath a ridge than beneath a lowland, due to the configuration of the water table. Consequently, where we are dealing with ridges buried beneath unconformable younger sediments, temperature gradients above such chilled ridges will probably be less steep than above the adjacent valleys.

2. (*a*) *Irregular deposition of sediments.*—Where sediments are deposited in uniform horizontal sheets, the isogeothermal surfaces in the strata formed will likewise tend closely to approach horizontality and parallelism. Where sediments are spread over an irregular surface, those deposited over the warmer lowland rocks may receive heat more rapidly than those deposited above adjacent ridges.

Irregularities in the rate of compacting, and local compacting of sediments above buried hills may, by irregular reduction of the percentage of water-filled pores, correspondingly alter the conductivity of super-ridge (as contrasted with super-valley) deposits. Compacting being so largely a function of both pressure and grain size, it is not, however, certain whether compaction would cause relative increase or decrease in super-ridge temperature gradients.

(*b*) *Expansion.*—When pore space is increased by elastic response to regional elevation and denudation, the water present, which formerly filled all pores, can

no longer do so, and local reductions in heat conductivity, due to increase in gas- or vapor-filled pores, may result.

(*c*) *Water movement.*—Meteoric circulation, during and after the accumulation of sedimentary beds, tends to produce a configuration of the isogeothermal surfaces similar to that of the ground-water table, but having less relief.

Juvenile waters and gases, *or water expelled by compaction from beneath the deeper part of a basin, may be discharged to the surface, either directly upward, or, more probably, laterally along the bedding,—such fluids delivering some excess heat to the overlying rocks along the avenues of discharge.*

3. *Dynamic deformation.*—Where sedimentary beds which were formerly longitudinal have been flexed and faulted, the isogeothermal surfaces, which originally lay parallel to the bedding of the sediments, have been similarly folded and dislocated. Consequently block uplifts and the truncated crests of the deformational folds should show relatively steep temperature gradients, whereas synclinal areas and in-dropped blocks should show subnormal gradients. In strongly deformed regions, friction incident to deformation of the folded and broken rocks may cause abnormally high regional temperature conditions, besides the local and differential effects just mentioned.

Where artesian water enters the outcrop of a bed truncated by erosion, it will tend to chill the bed on the intake side of the synclinal axis, and will tend to maintain the original temperature in the bed beneath an anticline lying in its path of movement beyond the synclinal axis. However, if before the folding took place the isogeothermal surface lay parallel with the bedding, the artesian circulation probably could not raise the sub-anticlinal temperature of the aquifer bed above the geothermal average for the bed as it existed before it was folded. Moreover, it seems probable that where a porous bed beneath the crest of an uplift is filled with gas, it may serve as a partial insulator,—heat tending to accumulate beneath such a gas-filled area.

4. *Vulcanism and intrusion.*—Where bodies of magma, or of plastic material such as rock salt and saliferous clays, are injected upward, or exude at the surface, they necessarily produce inhomogeneities which are productive of characteristic distortions and anomalies in local isogeothermal surfaces. An igneous or rock-salt plug, a mushroom-shaped laccolith, or a plate-like dike or sill, should each produce an abnormality of local isothermal surfaces reflective of its shape and size. A secondary and more far-reaching heating effect may also be induced by one or more waves of fluids evolved and liberated in the course of the crystallization of magma bodies,—such effect presumably being evident in certain regions featured by volcanic activity and by geysers, fumeroles, and hot springs.

The foregoing statement regarding inhomogeneities in the earth productive of irregularities of isogeothermal surfaces in the earth's crust is intended to be suggestive rather than complete, and can be greatly elaborated. It is furthermore hardly necessary to point out that temperature conditions now found to exist within local units of the earth's crust must in each instance result from the interplay of a number of the factors mentioned, or that the successful interpretation of the significance of observed temperature conditions is rarely, if ever, possible unless the geologic history of that region is known in very considerable detail.

# ORIENTATION OF CORES[1]

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## ABSTRACT

Orientation of cores should be of great value in geological investigations of subsurface structures. The historical development of orientation of cores since the early German method of the seventies is reviewed, recent California practice is touched on, and investigations by the writer since 1918 are described. Cores have recently been accurately oriented to more than 4,500 feet in depth. Such great improvements are possible over the present methods and equipment that orientation of cores offers one of the most promising methods for determining underground geological structure.

## INTRODUCTION

Orientation of cores comprises the establishing of the original underground position of cores, and should be of great value to petroleum geologists, because after a core showing bedding planes has been oriented, the direction of stratigraphic dip in the well can be determined.

As the practice of orienting cores in wells has not yet become general, the following words regarding its practical value will not be out of place.

The principal field of usefulness is in wildcat wells in which the known geological evidence is insufficient to determine the exact position of the structural axis. Wildcat wells ordinarily follow a long and expensive geological study of available surface outcrops, topographic features, subsurface correlations, and geophysical conditions, with an equally expensive land-leasing campaign. The geological study of conditions furnishes the evidence suggesting the presence of a structure favorable for oil, such as an anticline, a fault, or a condition of the facies within a limited area, but the size of this area may be several times as great as the expected oil field, so that the wildcat may very probably be in the unproductive part of the area. Among the many factors making it difficult to predict the exact position of a productive field are

[1]Read before the Pacific Section of the Association at the San Francisco meeting, November 21, 1929, and read before the Association at the New Orleans meeting, March 21, 1930. Manuscript received by the editor, February 10, 1930.

[2]Petroleum geologist and engineer, 5425 Chesley Avenue.

scarcity of evidence, misleading or misunderstood evidence, unconformities, asymmetric conditions, hidden faults, alluvium, and facies changes. Where the structure is believed to be anticlinal, or possibly faulted, orientation of cores can determine the true direction of dip in the well, making possible a much better selection of properties to retain, acquire, or reject, with a corresponding saving of rentals and bonuses, which form a huge sum in modern wildcatting. If the direction of dip is known from an oriented core, a second well can be located in a more favorable part of the area. Even if the first wildcat is unproductive, in many places the outlay for a second wildcat to follow up the information already obtained at great expense and on property already acquired is much to be preferred to abandoning the area and repeating the expense of acquiring information and acreage in another locality.

One of the most undesirable features accompanying a discovery by a wildcat, where acreage is subdivided into small parcels, is the host of competitors ready to drill immediately and force offsets on the discoverer, with the inevitable overproduction and low price of oil. After orientation of cores, funds ordinarily used for random protection acreage can be concentrated on the up-dip or favorable side of the well to lessen the number of competitors, offsets, and overproduction.

Another field of usefulness for orientation is in "post-hole" drilling for structure. Orientation of cores can be carried on simultaneously with search for marker or key beds. Where the dip steepens, the location of key horizons for correlation becomes more difficult and requires closer spacing of holes, with more frequent coring; however, orientation of cores becomes more accurate with steepening of dip.

Orientation may be of use also in prospecting for deeper oil sands beneath producing fields. Ordinarily the structure of the deeper horizons should approximately parallel that of the shallower horizons, but because of unconformities this may not everywhere be true, so that a deep well on the apex of the shallow horizon may miss the deeper horizon.

In the present stage of development the most favorable formation in which to orient cores is shale with bedding planes dipping at an angle of more than 5°. Massive formations are not satisfactory, because of lack of dips. Hard sand wears cutters out of effective shape too quickly and soft sand tends to crumble and plug the core barrel. Cross-bedding is more likely to be present in sand. In several places slickensided fault planes have been found and oriented in cores.

In the orientation of cores the two principal factors to take into consideration are (1) the difficulty of bringing samples or cores of the

formation to the surface in a satisfactory condition, and (2) the selection of suitable instrumental means for making the necessary records.

One of the earliest forms of core drill on record is the Kind[1] core drill used in Germany as early as 1844 in connection with a free-fall percussion system of drilling. Rotary core drilling was introduced about 1861 by Leschot,[2] a French engineer, in the form of the diamond drill used in the tunnels through the Alps. Since that time many improvements have been made in core drills, such as the double-barrel form, the bladed types

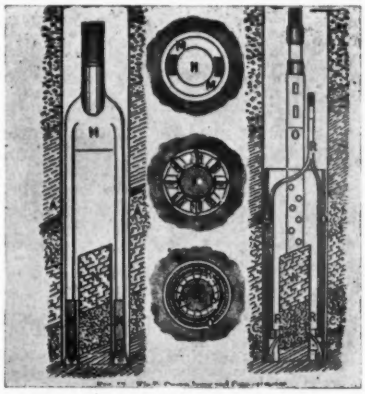

FIG. 1.—Kind core drill. From R. A. S. Redmayne's *Modern Practice in Mining* (Longmans, Green and Co., London and New York), Vol. 1, 3rd edition (1925), Fig. 53, p. 93.

for soft oil-field formations, the roller types for hard formations, the shot drills, the calyx core drill, the punch core drill, the cable-tool core drill, and improved forms for handling heavy mud circulation.

A few words regarding well-surveying methods may not be out of place, because of the use of surveying methods in orienting cores. Probably the oldest form of instrument for surveying bore holes is that devised by Nolten[3] in Germany, about 1874, having a glass bottle of hydrofluoric acid used to measure inclination, and a clock to clamp a magnetic compass used to determine direction. Later developments were the use

[1]R. A. S. Redmayne, *Modern Practice in Mining* (Longmans, Green and Co., London), Vol. 1, p. 91.

[2]J. R. Leschot, U. S. Patent 39,235.

[3]R. A. S. Redmayne, *Modern Practice in Mining* (Longmans, Green and Co., London), Vol. 1, p. 176.

of gelatine to congeal about a magnetic compass and pendulum devised by McGeorge;[1] the method of McFarland[2] of measuring the electric current variation in resistance wires which dip into a mercury bath; the Marriott[3] method, in which a pendulum varies the resistance by a rheostat; Oehman's[4] method, in which a magnetic compass and pendulum are photographed; the gyroscopic devices of Anschutz-Kaempfe;[5] the Briggs[6] clinophone; the graviscope of Wuensch,[7] in which a pendulum operates a stylus to chart inclinations; the Anderson[8] survey instrument in common use in California; the McLaughlin clinograph; and many others. These methods were developed in connection with the coal, salt, and water borings of Germany, the diamond-drill holes of the South African and Australian gold fields, the freezing processes of shaft sinking in Europe, and more recently in the oil fields of the United States.

Nearly all of the methods used for orienting cores can be grouped with the following general classes. The core barrel is oriented by measuring or orienting the drill pipe out of the hole as in the Kind[9] and other methods. An instrument is set in the bottom of the well and recovered attached to a core, as in the Vivian,[10] Kendall,[11] and similar methods. A core is cut and left standing in the hole, after which a core tube provided with a survey instrument is lowered into the hole to bring out and orient the core, as in the McGeorge[12] gelatine method and others. Recording instruments are attached to the core barrel during coring, as in the

[1] *Engineering*, Vol. 39 (London, March 13 and April 3, 1885), pp. 260 and 334.

[2] R. A. S. Redmayne, *Modern Practice in Mining* (Longmans, Green and Co., London), Vol. 1, p. 177.

[3] E. B. Durham, *Mine Surveying* (McGraw-Hill, 1913), p. 330.

[4] J. I. Hoffman, *Inst. Min. Met. Bull. 91* (April 11, 1912).
K. Haussman, *Glückauf* (February 15, 1908).

[5] H. Anschutz-Kaempfe, U. S. Patents, 1,313,367 and 1,411,896.

[6] A. D. Bryden, *Trans. Amer. Inst. Min. Met. Eng.*, Vol. 71 (July, 1926), pp. 431-47.

[7] *Eng. and Min. Jour.*, Vol. 111 (1921), pp. 949-50.

[8] A. Anderson, "Underground Surveys of Oil Wells," *Amer. Inst. Min. Met. Eng.* (February, 1929).

[9] F. Freise, *Osterreichische Zeits. für Berg- und Hüttenwesen*, No. 41 (October 13, 1906), pp. 526-30.

[10] *Ibid.*

[11] P. F. Kendall, British Patent 5,470 (April 15, 1887).

[12] "Clinograph or Bore Hole Test," *Engineering* (London, March 13, 1885), pp. 260-63.

Gothan[1] stratameter and later devices. The wall of the well hole has been photographed by a special camera, as in the Atwood,[2] Reinhold,[3] and other devices.

### DESCRIPTION OF EARLY ORIENTATION METHODS

The Kind[4] method is probably the earliest method used in orienting cores. It is described as early as 1888, after several years of use in Germany, and probably dates back to 1872. By this method a core was drilled by a forked bit using the Kind freefall percussion system of drilling and a core lifter of special construction lowered over the core. The core was then drawn to the surface, care being taken not to twist the rods. Two index arms were held against the rods, one at the derrick floor and one by a man in the derrick near the top of the drill rod, these index arms being for the purpose of aligning the pipe against twist. This method was used to a considerable extent in Germany before diamond drilling was known. After diamond drilling came into general use, the method was found not practical because of the small diameter of diamond-drill holes.

Vivian,[5] an American diamond-drill engineer, devised a somewhat different method of orienting cores. A pilot hole was drilled a few inches and an instrument case was lowered into the hole so that a part of it was fastened into the pilot hole. In this case a compass needle was clamped by a weight used in setting the case. A core was taken recovering the instrument case attached to the upper end of the core. Considerable difficulty was caused by the pilot hole filling with cavings, by concussion during coring, and by the core breaking, so that the method had very little usage.

McGeorge,[6] who invented the gelatine method of surveying bore holes, also realized the importance of orienting cores. He was the first to appreciate the importance of determining the inclination of the core at the time of orientation. By his method a core was drilled without a

[1]H. Thuman, "The Gothan Stratameter," *Glückauf* (January 18, 1902), pp. 55-57.

[2]J. T. Atwood, *Eng. and Min. Jour.* (May 18, 1907), p. 944.

[3]"Photographic Apparatus for Boreholes," *Colliery Engineering* (August, 1926), p. 371.

[4]F. Freise, *Osterreichische Zeits. für Berg- und Hüttenwesen*, No. 41 (October 13, 1906), pp. 526-30.

[5]*Ibid.*

[6]E. F. McGeorge, U. S. Patent 281,772 (July 24, 1883).

core-catcher in the barrel and the core left standing in the hole when the core barrel was withdrawn. A second tool having a core-lifting tube set eccentric and an instrument case were lowered over the core stub and allowed to set until the gelatine congealed about a compass and pendulum within the case. The drill rod was then twisted so that the eccentric barrel sheared the core off, and it was then drawn to the surface and the orientation determined from the compass and pendulum. Objections to this method were the interference of cavings, fracturing of the core, and difficulty of congealing gelatine at underground temperatures.

Lubitsch[1] improved on the Kind method to adapt it to diamond-drilling. A core was first drilled without a core-catcher and the stub left standing in the hole. A second tube was then lowered over the stub and it was drawn out and oriented as in the Kind method. This method was more adaptable to small holes, but grit and cavings were troublesome, and many cores broke off.

Kendall[2] invented an apparatus about 1887 which was set in a pilot hole, the Vivian method, but the compass in the case was clamped by lifting off the weight of the setting tool. A core was then taken with the compass attached to the top of it.

Wolff,[3] about the same time, invented an apparatus which was lowered over a stub of core in a hole and in which clockwork was used to clamp a magnetic needle after a predetermined time. The core was then removed and oriented from the clamped needle attached to it.

The Gothan[4] stratameter was invented in Germany about 1899, and is the earliest form of orientation device in which a recording apparatus is attached directly to a rotary core barrel during coring. This apparatus was used to depths of 1,000 feet in Germany. A single-barrel core drill is used, and an instrument case is attached to the upper end. In this case is a magnetic compass, a plumb bob, a soft sheet, and a clock. Before being lowered into the hole, the clock is set to trip at a predetermined time. A core is drilled and the barrel allowed to remain quiet until the clock trips. When the clock trips the compass is clamped and the plumb bob dropped on the soft sheet to leave an impression or

[1]F. Freise, *Osterreichische Zeits. für Berg- und Hüttenwesen*, No. 41 (October 13, 1906), pp. 526-30.

[2]P. F. Kendall, British Patent 5,470 (April 15, 1887).

[3]Moritz Wolff, German Patent 47,221 (May 23, 1889).

[4]H. Thuman, "The Gothan Stratameter," *Glückauf* (January 18, 1902), pp. 55-57.

No. 649,636. Patented May 15, 1900.

H. GOTHAN.

APPARATUS FOR DETERMINING DIRECTION OF GRADIENTS OF STRATIFIED MASSES.

(Application filed May 1, 1899.)

(No Model.) 2 Sheets—Sheet 1.

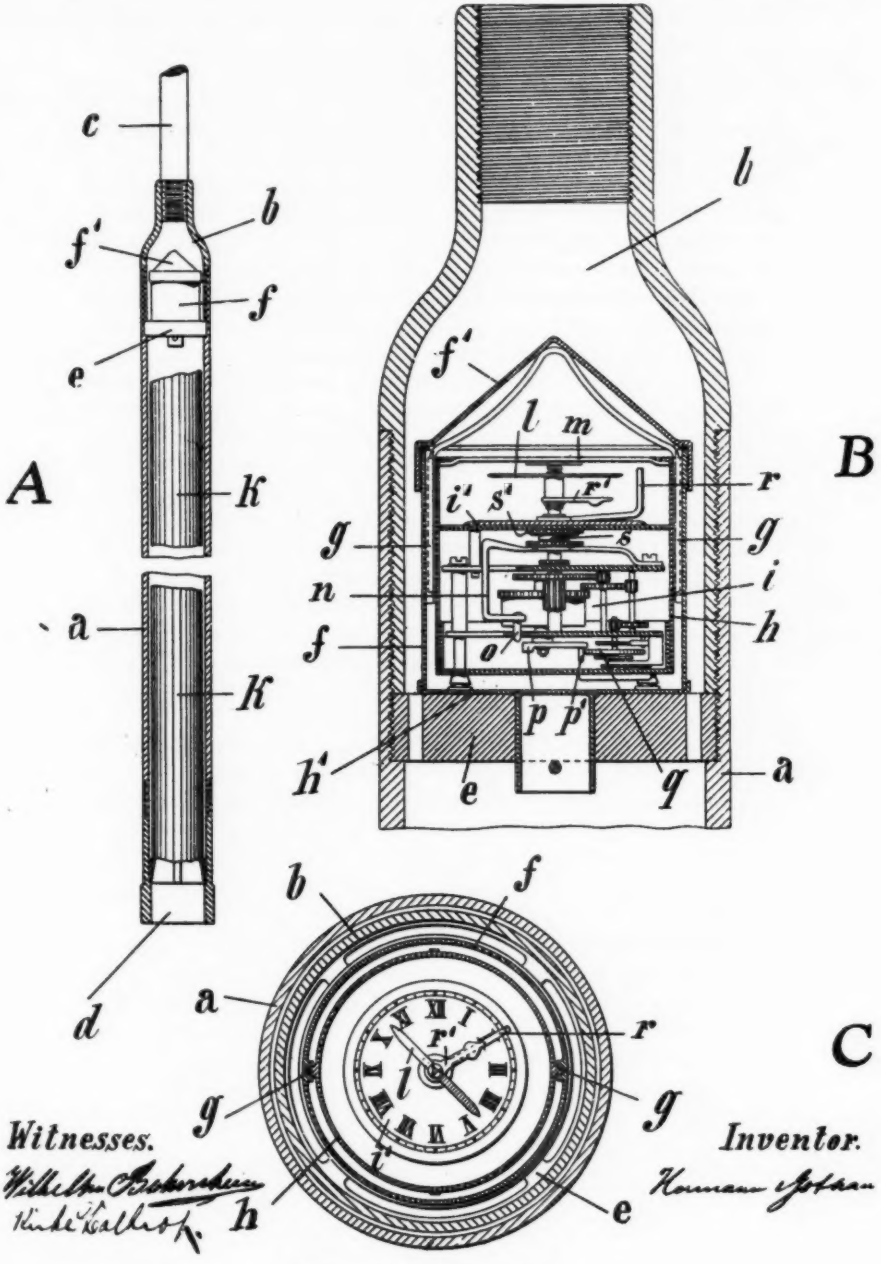


FIG. 2.—Gothan stratameter.

dent. The core barrel is then withdrawn and the core orientation determined from the clamped compass and plumb-bob dent. Gothan also provided a swiveled stand, so that the position and inclination of the core could be reproduced to visualize the orientation.

Meine,[1] of Berlin, utilized a messenger ball dropped down the drill rod instead of a clock to trip a clamp for locking a compass needle on a core barrel.

Koerner[2] described a complicated device containing a motion-picture machine and another device in which a messenger weight forced pointers into a cork. Both devices were to show inclination, the drill pipe and core barrel being oriented out of the well by measuring each stand.

In the Goodman[3] device, described about 1908, a clock was used to clamp a magnetic compass and pendulum, these being attached to the top of a barrel lowered over a stub core left standing in a well.

An elaborate and interesting apparatus was described in Belgium about 1909 by Jean Florin.[4] An instrument case is lowered into a hole by a cable and set down on the stub of a core in the hole. A soft lead surface on the lower face of the case takes an impression of the top of the core stub. Within the case is a copper disc coated with a phosphorescent material and supporting a pivoted magnetic compass needle. A lens midway in the case throws the image of the light disc and the dark needle on a photographic plate at the opposite end of the case when a shutter is shifted by contacting the bottom of the hole. The case is filled with clear water and a 20- to 30-minute exposure is required. After the apparatus is removed and the photograph developed, a core is taken and correlated with the compass photograph by the impression of its upper end.

About 1907, J. T. Atwood[5] described a camera for photographing the walls of a hole filled with liquid and used it to depths of about 200 feet in a well in Illinois. It consisted of a case having a window, an electric light for illuminating the walls of the well, a mirror, a lens, a photographic film, and a motor-driven reel. It was lowered into the hole by a

[1]R. A. S. Redmayne, *Modern Practice in Mining* (Longmans, Green and Co., London), Vol. 1, p. 180.

[2]G. Koerner, British Patent 7,797 (March 31, 1906).

[3]J. Goodman, British Patent 23,003 (October 29, 1908).

[4]Jean Florin, Abstract from *Analles des Mines de Belgique, Eng. and Min. Jour.*, Vol. 47 (1909), p. 854.

[5]J. T. Atwood, *Eng. and Min. Jour.* (May 18, 1907), p. 944.

cable, and photographic exposures were made by operating an electric switch at the ground surface.

Recently a more elaborate camera has been developed in Holland by Reinhold,[1] in which the walls of a well can be photographed to greater depths. He provides packers for furnishing a space for clear water at the horizon to be photographed.

In the Mitchell[2] device, developed about 1924, a pilot hole is drilled and a capsule inserted into it as in the Vivian method. The capsule contains a magnetic compass needle suspended as a plumb bob in warm gelatine which is allowed to congeal. A core is taken having the capsule attached to the top of it and oriented from the fixed compass.

The Dixon[3] device is a complicated apparatus having a gyrocompass, a clock, a motor, and a rock denter enclosed in a case which is lowered into a hole on an electric cable. A mark or dent is made on the bottom of the hole and the position of the dent recorded in the case. The instrument is removed from the hole and a core is taken which is oriented by the dent or mark on the upper end of it.

The Hall-Armentrout[4] device has a gyrocompass driven from electric cells on the upper end of a core barrel, and a trip rod extending down to the lower end of the cutters and dragging on the bottom of the hole during drilling. When a core has been completed and the core barrel is raised, the trip rod lags behind and operates a clamp to lock the gyrocompass. The accuracy of this tool is questionable, because of the difficulty in constructing an accurate gyrocompass of small diameter, and because of the twist in the core between the instant of raising off bottom and the instant the gyrocompass is locked.

### RECENT CALIFORNIA PRACTICE

Most of the devices for orienting cores already described originated in Europe or the British colonies in connection with diamond drilling. They were designed for hard rocks such as occur in coal regions, for use in shallow holes which did not deviate greatly from the vertical, and for clear water circulation.

In California, different geological and mechanical conditions prevail. Much heavier drilling equipment is used and it is frequently pushed

[1] "Photographic Apparatus for Boreholes," *Colliery Engineering* (August, 1926), p. 371.

[2] J. S. Mitchell, U. S. Patent 1,566,499 (December 22, 1925).

[3] A. F. Dixon, U. S. Patent 1,630,694 (May 31, 1927).

[4] E. B. Hall and A. L. Armentrout, U. S. Patent 1,656,809 (January, 1928).

to the limit of its strength. Heavy mud circulation is essential, and pipe must be kept continuously moving when in the hole. Wells are deep and many deviate greatly from the vertical. The heavy mud pumps now used cause objectionable vibration of delicate instrumental parts such as pendulums and compasses. By far the greatest difficulty in California has been the difficulty in cutting and extracting a core without twisting it from its original position before recording an observation of its position.

Probably the first attempts to orient cores in California were made by the Shell Company of California near Oilfields[1] and in other parts of the state about 1919. A form of stratameter of the Gothan type was tried, but with indifferent success because of difficulty in obtaining cores untwisted in the barrel.

At that time core drills were not as well developed as they are now and it was almost impossible to recover cores in unbroken lengths of more than a few inches in California formations. Very little was done in California toward orientation of cores for several years following 1921.

An interesting method of orienting cores was recently described.[2] A series of cores is taken in one well, the magnitude of dip in each core is measured, and the course of the well is surveyed. Two essential conditions are necessary: (1) the inclination of the well must change appreciably, and (2) the actual dip of the formation throughout the length of observation must remain constant in magnitude and direction. Small sticks are passed through blocks or plates at such angles that each block represents the magnitude of a core dip relative to the stick which represents the well. Each stick is then set upright on a base and tilted into the inclination and direction determined by the survey. The blocks are then rotated on each stick as an axis until the blocks lie in parallel planes, the direction of these planes being the dip of formation. This problem can also be solved mathematically.

Between 1925 and 1928, one of the oil companies in California drilled many post holes for geological information, in the course of which process many cores were oriented. Cores were taken with core drills of several types and oriented by measuring the pipe as it was pulled from the well by a method which in some respects resembles the old German method of Kind. A mark is made near the rotary table on the drill pipe facing

[1]R. M. Barnes and R. E. Collom, *California State Min. Bur. Summary*, Vol. 6, No. 12 (June, 1921).

[2]Alexander Anderson, Amer. Inst. Min. Met. Eng. meeting, Los Angeles, California (November 27, 1928).

a range flag, and the drill pipe is pulled up. At the top of the derrick the position of the mark is observed on a semicircular graduation attached to a pointer stick pointed at the range flag. The position is then called to the floor observer, who makes a mark on the next stand. Each stand is marked, and the last mark shows the orientation of the core barrel. The core is then carefully removed from the barrel, care being taken to note its position relative to the last mark. Rotary core drills of several types were used without very satisfactory results. Most orientations were made with a punch core barrel which consisted of a short core tube with a cutting end attached below a heavy rotary jar so that it could be run on drill pipe. This was lowered to the bottom of the hole and the tube driven into the formation by blows from the jars. Cores with an average length of about 1 foot (few exceeding 2 feet) have been taken and oriented to depths as great as 2,500 feet. This core drill is best in soft formation.

The Associated Oil Company of California did considerable experimental work on orientation of cores, about 1925. An ingenious instrument was developed by G. D. Hanna[1] for attachment above a core drill. This instrument consists of a magnetic compass, a timing mechanism, and a weight freely swiveled on a vertical axis. Orientations with this device have been attempted to depths as great as 2,500 feet. A modified form of this device has been developed and found satisfactory for surveying the course of wells.

Within recent years core drills of two or three other types have been tried or proposed in which a magnetic needle carried by the core barrel is locked in position while in the well. Difficulty has been encountered in preventing the core from twisting out of position before the needle is locked. Furthermore, the jerky motion imparted to drill pipe by the mud pumps ordinarily used causes the needle, together with a pendulum, to shift position frequently so that it may be locked in a misleading position.

### MACREADY INVESTIGATIONS

During 1918 and 1919 the first experiments on orientation of cores by the writer were carried on in connection with the asphalt and petroleum deposits of Trinidad and Venezuela. A small rotary core drill was first tried, with unsatisfactory results. Better results were obtained by the use of driven cores taken with a portable outfit. The equipment was very light and simple. The core barrel was 1¼-inch pipe, with

[1]G. D. Hanna, U. S. Patent 1,665,058 (April 3, 1928).

a sharp, carefully made shoe at the lower end cutting a 1-inch core. The core barrel was corked at the lower end and filled with soap suds to exclude débris, lowered to the bottom of the hole by drill rods, and driven down by blows from a 200-pound weight. Ordinarily 5-foot cores were taken, although in several holes 10-foot cores were recovered. The average recovery was about 75 per cent. After the core barrel was pulled out, 2-inch pipe was driven to the bottom for casing and the hole cleaned out to the bottom by a hydraulic churn drill. In orienting, the drill rod was measured out in 10-foot lengths by marking the top of each joint near the floor with a pencil or chalk and turning the mark to face in the same direction after the rod had been pulled up for the next joint. The depth of the deepest hole was 250 feet. The formation in Trinidad was soft clayey shale with oily streaks and asphalt, some of the holes being in the Trinidad asphalt lake. The dip directions were irregular, which was attributed to shifting of asphalt. In Venezuela the formation drilled was flat-bedded swamp alluvium, and holes were relatively shallow.

These experiments were on a small scale, with crude equipment, but they showed a promising method for mapping structure underlying alluvial areas where outcrops were not available. At that early date, however, core drilling in connection with oil fields was an unheard-of procedure, and, as a means of obtaining geological information regarding oil, was regarded as a ridiculous extravagance.

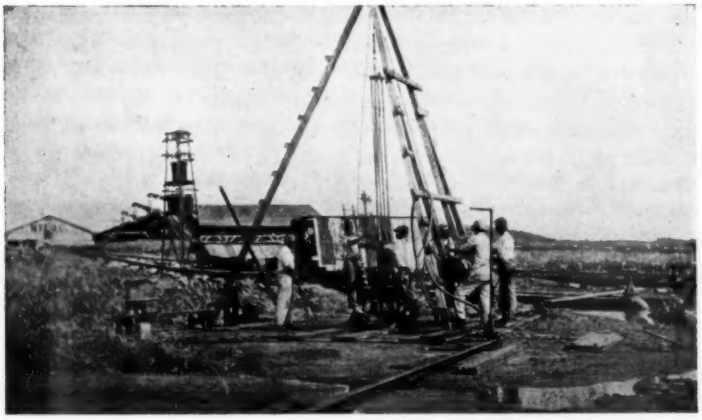

FIG. 3.—Coring on Trinidad asphalt lake.

A year or two later, some of the crude rotary core drills used in California were observed and the suggestion made by the writer that driven cores would be more satisfactory in the soft formations and would be more easily and accurately oriented. The result of this suggestion was the development of the punch core drill, which was used to a considerable extent for several years.

The writer has devoted the past three years exclusively to the study of orientation of cores. An extensive series of experiments has been carried out by use of a portable rotary drilling machine and core drills of several types in addition to many deep runs.

The principal features requiring experimental work included: (1) improvement of details of coring methods and equipment to avoid twisting the core out of its original position before recording, (2) selection of suitable instrumental equipment for recording the position of the core, and (3) selecting proper timing arrangements so that the record would be made at the most reliable stage of coring.

Coring details required much experimenting, and much still remains that can be done. In California most drilling is done with rotary tools. Rotary core drills, although very efficient in footage recovery, may cause the core to twist out of its original position, thus spoiling the orientation. It was early evident that for orientation the double-barrel type with a floating or swiveled inner barrel would prove most satisfactory, but even this form in practice would not unfailingly take untwisted cores in soft formation until considerable experimenting had been done. Thrust bearings caused little difficulty unless broken, and several forms were tried. Circulation was conducted between the outer and inner barrel to the extreme lower end. The greatest difficulty seemed to be in the lower few inches of the core drill. The most efficient arrangement found to date has been the Elliott cutter head with a floating inner barrel having a shoe similar to the Trinidad drive shoe, but fluted internally to graduate the core, a compression spring on the inner barrel to prevent it from chattering and vibrating so as to shear off the core, and a mud guard to prevent débris from plugging the inner barrel. With this arrangement, cores have been recovered in shale, exceeding 15 feet in length above the shoe, without a sign of twist or fracture.

Selection of suitable instrumental equipment was not very difficult because of the many forms available in connection with well surveying. For inclination, indicators of the pendulum type seemed easier to use in making a record than those of the liquid-level type. For azimuth, there was the choice of: (1) actually surveying the pipe out of the hole,

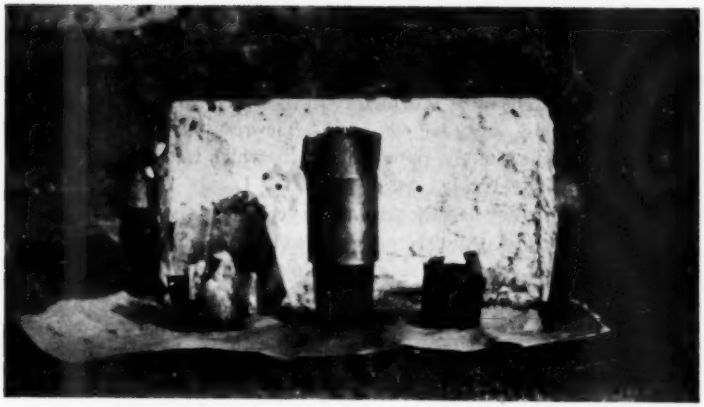

FIG. 4.—Forms of cutter heads.

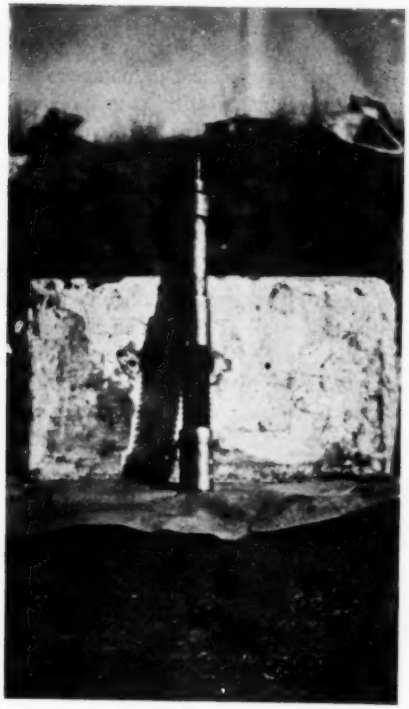

FIG. 5.—Compression spring on inner barrel.

FIG. 6—Mud guard and thermometer case.

FIG. 7.—Block used in testing core twist.

which is laborious and of questionable accuracy; (2) the gyroscope and gyrocompass, which were investigated but which, though theoretically attractive, offered delicate mechanical problems which seemed difficult to solve, and (3) the magnetic compass which, though not reliable near iron, was finally accepted as sufficiently accurate for orientation. For recording the positions of the indicators, several methods were available, such as: (1) variation of electrical resistance, which is not practical for the magnetic compass, (2) clamping the compass and pendulum, which can be done but may record at a misleading position during swinging or may be altered by shaking out of position after recording, (3) marking on a chart, which places too great a weight load on the compass needle, and (4) photography. Photography was chosen because both pendulum and compass needle can remain freely swinging during recording and do not have to touch anything that may disturb their positions, and because the photograph automatically averages the position if there is any swinging. This latter feature is particularly valuable where circulation is shaking the drill pipe and causing the needle to make a hazy but legible photograph. It was found best to have the recording instruments attached directly to the inner barrel, where there was less possibility of change relative to the core.

Considerable experimenting was required to select suitable timing arrangements. One of the first forms was a clock used to flash the light for the photographic exposure, which was set before being lowered into the hole to act at the instant when it was decided that coring would be complete. It was found difficult to estimate the exact instant of completion of coring, which difficulty caused slight delays, but the strongest

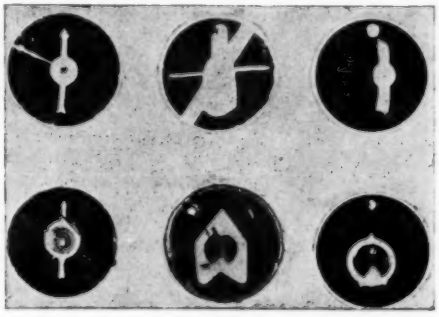

FIG. 8.—Types of compass-pendulum photographs.

objection was that the time of coring varied, so that, if the core was completed in advance of the exposure, it was necessary to rotate the pipe without digging, to prevent freezing, and this rotation had a tendency to twist the core out of position; or, if the core was made slowly, the amount obtainable was not sufficient. To overcome these difficulties the spline swivel was made. The spline swivel is a heavy tool resembling a rotary jar, which is placed between the core drill and the drill pipe. By raising and rotating the drill pipe a few turns the instrument can be tripped at any time desired. The spline-swivel type has been the most frequently used form, and has oriented cores to over 4,500 feet in depth, but it has the objectionable features of being bulky and expensive to construct and of requiring practice for efficient operation.

The most recent form developed makes use of a long photographic strip on a reel; it photographically records positions of the pendulum and compass at regular intervals so that a complete survey of the well can be made and several positions of the core barrel recorded during

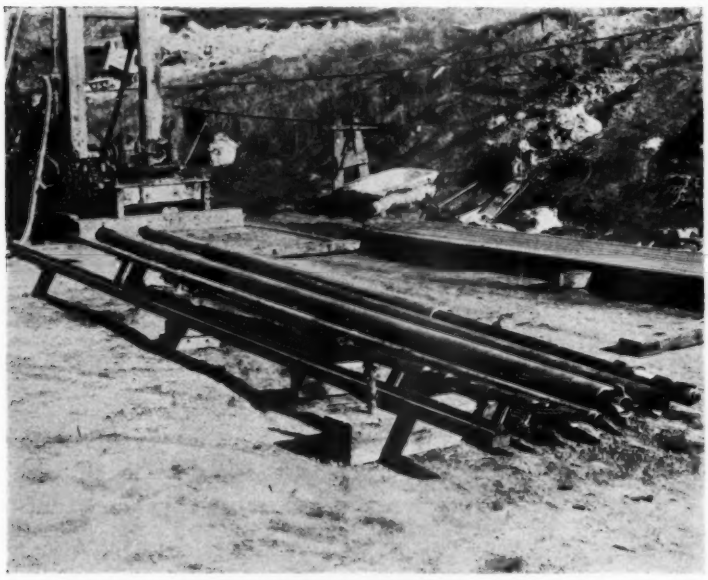

FIG. 9.—Orientation core drill of spline swivel type.

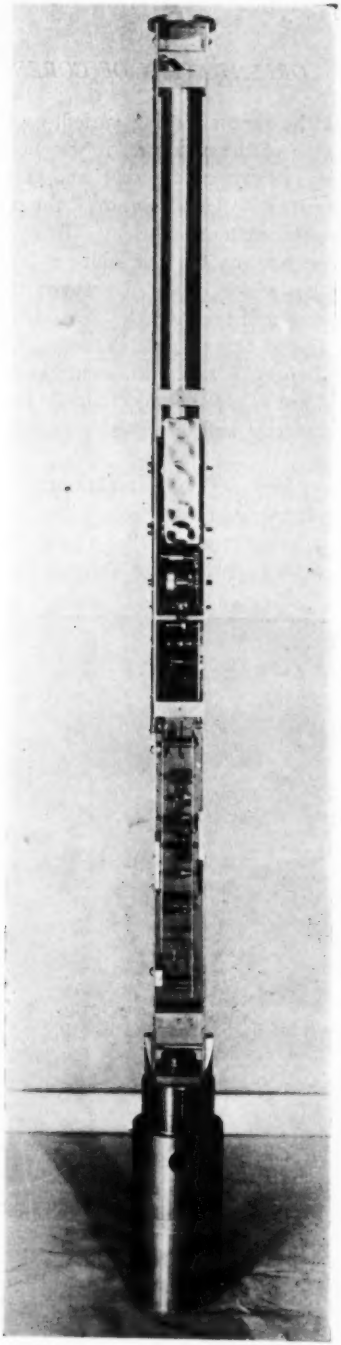

FIG. 10.—Multiple-photograph orientation instrument.

coring. The spline swivel is omitted and coring procedure is almost the same as for ordinary coring. Approximately 75 photographs can be taken at intervals of 1, 2, 4, or 8 minutes, and the change of interval can be made in a few seconds before the equipment is lowered into the hole.

The accuracy of orientation has been checked on many occasions. As a check on the accuracy, the experimental work was carried on by

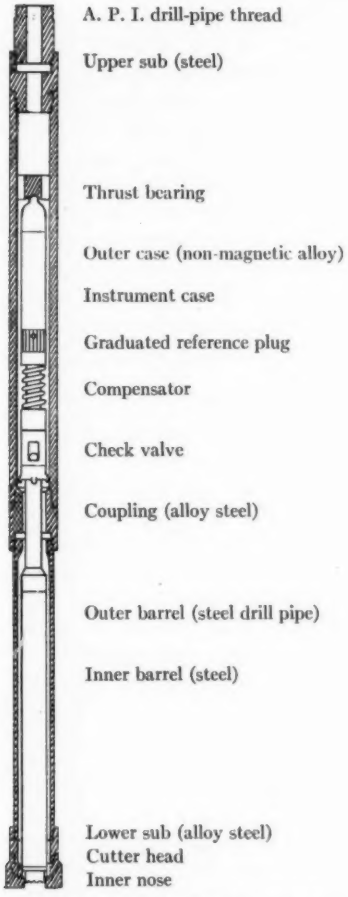


FIG. 11.—Assembly of Macready orientation core drill. Outer unit in section, showing view of inner unit.

drilling beside an outcrop of known dip. Nearly all orientations corresponded within 25° with the outcrop direction, and within 5° with magnitude of dip. The few exceptions could be attributed to causes in the course of trying new features. In one series of nine successive cores, the dip determined by eight of them agreed within 25° with the outcrop direction, and the magnitude within 5°. As a check on the accuracy of the magnetic compass in the vicinity of drill pipe, the instrument was rigidly attached to the drill pipe and tripped while suspended in the hole, at a depth of less than 100 feet. The drill pipe was oriented out by a range flag, and it was found that the compass direction was correct. In another hole, at a depth of more than 4,500 feet, a series of six runs resulted in five orientations. Not every dip was distinct, but all corresponded within 90° and the three most distinct dips within 10° in direction. In another hole, two cores were oriented in a series of three runs at a depth of 3,000 feet and corresponded within 25° in direction. The inclination of this hole corresponded very closely with the results of a survey by another method. It has been found very important to record the inclination of the well hole at the point of coring for a correction of the apparent dip of the core, and this correction has in several places amounted to nearly 45° in direction.

## CONCLUSIONS

By orientation of cores, the true magnitude and direction of dip at the bottom of a well can be determined.

This information can be used to advantage by operators of wildcat and other wells to enable them to make better selections of acreage as their wells progress. In the event of the discovery of a new field, orientation of cores can be useful in reducing the number of competitors, offset wells, and the resulting overproduction.

Attempts have been made to orient cores since the seventies, and many devices have been used and suggested. The principal developments have been the early Kind method, the Gothan stratameter, orientation in California within recent years to 2,500 feet in depth, and the more recent orientations by the writer to 4,500 feet in depth.

# ACCURACY OF BORE-HOLE SURVEYING BY ORIENTATION FROM THE SURFACE[1]

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## ABSTRACT

The paper deals with the surveying method in which direction, relative to points of the compass, is determined at the ground surface by observing the degree of rotation of a pipe which has an instrument rigidly attached to its lower end. This method is distinguished from those using some sort of compass within the instrument itself.

The practice of surveying bore holes will probably be increased within the oil industry. The object of the writer is to present data showing the degree of accuracy which may be expected. Specific description of instruments and details of their operation are not treated. Results of surveys made during the past twenty years in various lines of industry, aside from oil, are presented in such a manner as to indicate the degree of accuracy which has been obtained.

Theoretical considerations are mentioned but not discussed.

There is a description of a unique series of tests made at an oil well for the purpose of determining accuracy of several instruments and several methods. Maps and other data accompany the description.

There are brief descriptions of results and their meaning as obtained by means of duplicate surveys conducted at various oil wells in the course of regular industrial operations.

The conclusion of the writer is that the method under proper manipulation is amply accurate to meet the requirements of the oil industry.

Surveying the underground course of oil wells is a practice which has demonstrated its utility and will doubtless come into more widespread use. There has been manifest a certain timidity on the part of oil operators to survey their wells, due to possible legal complications involving the question of ownership of underground deposits beneath different tracts of land. This obstacle is probably not so important as it might at first seem. The oil industry is one of the most progressive and can be depended upon to solve such problems satisfactorily as soon as they are fairly confronted and studied. A recent illustration of such ability is the subject of unit operation of oil deposits, which was, not more than five years ago, unanimously condemned, yet now a majority of the most influential organizations in the industry are endeavoring to perfect the plan and put it into use.

[1]Read by title before the Association at the New Orleans meeting, March 21, 1930. Manuscript received by the editor, February 24, 1930.

[2]850 Subway Terminal Building, 417 South Hill Street.

Since the drilling of deep wells has become necessary, their cost has mounted rapidly and the large investments in such work makes imperative the consideration of all pertinent facts and conditions. The legendary policy of the ostrich hiding its own head and imagining that its entire body is thereby protected has no counterpart in the mental processes of the progressive oil operator. Success in the oil business has followed the ability to face facts, whether pleasing or not, and to adjust operations in accordance with the demonstrated conditions.

It has been only a comparatively short time since investigations demonstrated the lamentable and widespread results arising from failure to drill wells vertically. In this short period there has been such a remarkable advance in drilling operations that few extremely crooked holes are now drilled. However, in order to drill wells vertically it is necessary to spend more time and money than before, and there is doubtless an economic limit which it will be found unnecessary to exceed. The determination of the economic limit for straight drilling, in addition to the need for complete information as to underground conditions in order to direct new production and conservation methods, will stimulate bore-hole surveying.

As instruments and equipment for surveying wells are now available for use by geologists and engineers, it seems timely to present data showing what degree of accuracy may be expected from different methods. It is not the purpose of the writer to describe fully the details of manipulation of any particular process, but merely to set forth the results which can be obtained by one general method which has been thoroughly tested by actual use in many oil wells.

Any survey, whether on the surface or underground, must yield data from which both a plan and vertical cross sections can be drawn, if the survey is to be considered complete. The mere finding of vertical angles along the course of an oil well, as determined by the very useful acid bottle, does not constitute a complete survey. In addition to measuring inclination, it is also necessary to determine the horizontal components of the various sections of the hole, or, in other words, to determine its direction or orientation.

The art of bore-hole surveying is not new, and technical literature affords many descriptions of apparatus and methods. However, none of the described methods seems directly applicable to oil-field operations, and each requires certain adaptations in order to be quickly and economically used.

In all surveying methods, orientation, which is equivalent to the measurement of angles in horizontal planes, is accomplished in two ways.

One method involves the use of an instrument containing some sort of compass which indicates the direction toward which the instrument is inclined. The compass may be of either the magnetic or gyroscopic type. The second method involves the use of an instrument inserted into the hole by means of tubing to which it is rigidly attached, and the direction of inclination of the instrument is determined by observing the degree of rotation of the part of pipe projecting above the ground surface. The latter method is more particularly considered in this paper.

Both compass orientation and orientation from the surface have been extensively used. The magnetic compass seems to have given satisfactory results where the rock was not magnetic. The magnetic compass will not function satisfactorily inside of iron or steel pipe; therefore, it is useless in oil wells where casing is present. Orientation from the surface has been extensively used to survey bore holes in magnetic iron deposits.

Surveying equipment developed for oil-field use and depending upon surface orientation includes the ordinary tubing or drill pipe with which all wells are regularly provided. The instruments are light and compact and their handling involves nothing but the routine procedure common to inserting either tools or pumps in wells. Some instruments are of simple construction and their operation is but little more difficult than that of an ordinary surveyor's transit. Of course the operator should have as much technical training as is required to conduct ordinary surveying and mapping operations.

Widely discrepant results have been reported from attempts to survey oil wells, and the accuracy of the different processes has been questioned. It is impossible to state whether or not a particular survey was accurate or otherwise unless it is known exactly what procedure was followed. Recently published popular descriptions of some instruments indicate that they have been designed without knowledge of the limitations imposed by nature, and it is probable that some attempts at surveying have been made without sufficient regard to the physical and mathematical laws which govern such procedure. However, the older descriptions appearing in purely technical publications give data upon which opinions as to results can be reasonably based.

Probably the most exacting requirements for accurate surveying methods have accompanied the drilling of many bore holes around a small plat of ground which was to be frozen so that a mine shaft could be excavated. The distance between such bore holes is commonly less than 3 feet and they are carried to depths ranging from 500 to 1,500 feet. Horizontal deviation of not more than 35 inches at a depth of 420 feet

is found in one set of specifications.[1] And in another hole drilling is reported to have been so nearly perfect that there was a horizontal deviation of only 1¾ inches at a depth of 534 feet.[2]

It is not probable that the technical men in the oil industry will soon be called upon to equal such results either in drilling or in surveying, but it is interesting to know that both purposes can be accomplished. In the last mentioned hole, orientation was from the surface, whereas the method was not specifically described in connection with the other holes.

In the course of diamond-drill prospecting in the iron deposits in Michigan, both the magnetic compass and surface orientation have been used and checked against each other.[3] In one hole, 1,697 feet deep, having a diameter of about 2 inches with a total horizontal deflection of about 262 feet, plats by the two surveying methods checked each other within 12.7 feet at a depth of 1,500 feet. The author states that repeated surveys indicated that in several places the magnetic-compass bearings did not agree because of the presence of casing which had been left in the hole. It is interesting to observe the accompanying tabulated record which makes a comparison between compass-bearing and surface orientation at different depths.

| *Depth (Feet)* | *Inclination (Degrees)* | *Course of Hole* | |
|---|---|---|---|
| | | *Magnetic Compass* | *Surface Orientation* |
| 100 | 1 | N. 73° E. | N. 85° E. |
| 300 | 2¼ | S. 42° E. | S. 36° E. |
| 500 | 4 | S. 24° E. | S. 2° E. |
| 700 | 3½ | S. 38° W. | S. 30° W. |
| 900 | 5 | S. 25° W. | S. 47° W. |
| 1,100 | 11 | S. 51° W. | S. 52° W. |
| 1,300 | 19 | S. 77° W. | S. 81° W. |
| 1,500 | 24¼ | N. 85° W. | N. 86° W. |
| 1,700 | 26 | S. 77° W. | No test |

The course of the hole is shown by Figure 5, which is computed and platted from the foregoing tabulation. It is particularly interesting to observe the comparatively slight difference between the two surveys, although the bearings of some of the courses are widely divergent. The discrepancies, however, are in the opposite directions; therefore, compensating. These two surveys were each comprised of only seven separate courses or readings, and comparison of these with oil-well surveys consisting of many times more readings shows the latter to be relatively more precise.

[1]J. Riemer, *Shaft Sinking Under Difficulties* (New York, 1907).

[2]Henry Briggs, *Royal Society of Edinburgh*, Vol. 46 (1926), pp. 223-29.

[3]E. E. White, *Trans. Amer. Inst. Min. Met. Eng.*, Vol. 44 (1912), pp. 77-79.

White says that surface orientation is accurate only if rods turn easily in the hole, which they ordinarily do except in holes of great depth, low inclination, or excessive curvature. Under these exceptional conditions he says that, unless the hole is rifled, twist can probably be removed from the pipe by raising or lowering it a few feet. This latter prediction has been amply demonstrated to be correct in recent oil-well surveys, as will be noted.

One of the most interesting reports relating to the surveying of bore holes by surface orientation describes work done at magnetic iron deposits in Sweden.[1] A detailed technical report of the methods used and the results obtained was published after an exhaustive investigation by a technical commission.[2] In that report it is noticeable that the general shape or divergence of the bore holes investigated was similar to occurrences found in oil fields. One hole 1,300 feet deep was deflected 488 feet, and the inclination from the vertical ranged from almost nothing at the surface to 40° at the bottom. The diameter of the hole ranged from 2¼ inches at the top to 1½ inches at the bottom.

Two examples are cited by Lundberg in which surveyed holes were later intersected by mine workings, and actual checks of survey accuracy were thereby obtained. One hole 450 feet deep, vertical at the top and inclined 5° at the bottom, checked within less than 2 feet. The second hole was 430 feet deep with 100 feet deflection which was found in the mine workings "almost exactly at the spot where it had been indicated to be." One hole 1,000 feet deep with 360 feet deflection was repeatedly surveyed with identical results.

Lundberg is of the opinion that the method fully answers the needs for diamond-drill holes. Petersson states that

> In order to test the reliability of this method, the commission have carried out thorough and practical tests in Klacka Lerberg and Streiberg, and good results have been attained. It was found that a string of tubing is not exposed to any torsion worth mentioning as a result of friction in the bore hole, not even when the bore hole may be curved.

Having briefly reviewed the results obtained in other industries, it is pertinent to present results observed in the oil fields. However, it may be well to pause in the midst of consideration of definitely ascertained facts to mention the theoretical side of the problem. The writer has heard many discussions bearing on the impossibility of accurate surveys at great depths where surface orientation is depended upon.

[1]Sven Lundberg, *Eng. and Min. Jour.* (April 26, 1924), p. 690.

[2]Walfr. Petersson, *Jernkontoret Annaler* (Stockholm, May 31, 1922), pp. 224-62.

Many of the arguments advanced have been both ingenious and stimulating, but as a basis for technical discussion they have lacked the support of results obtained by actual tests. Furthermore, the rigid and straightforward process of reasoning requisite to consideration of a problem in analytical mechanics has commonly been absent. Imagination has too frequently been relied upon in place of observed facts. Therefore, until theoretical discussion is placed upon a more substantial foundation, it seems scarcely necessary to depart from the consideration of observed conditions.

During the past year the writer has had occasion to survey a great many oil wells ranging in depth from 4,000 feet to more than 8,000 feet. As all of this work has been performed for other people, the results were confidential and not available for publication. However, an opportunity was recently presented, through the coöperation of one of the large oil companies operating in California, whereby many surveys could be made for the primary purpose of comparing several methods and determining their degree of accuracy. Permission to use certain data has also been obtained from several other oil companies. Where a continuously recording instrument is used, it is possible to make a duplicate or checked survey without the expenditure of much additional time, simply by taking the results obtained while the instrument is being withdrawn from the well in addition to those obtained while the instrument is being run into the well. With such an instrument it is also possible to perform various experiments to determine what is happening underground during the course of a survey.

In making this series of test surveys, a well was chosen of which repeated surveys had already been made during the process of drilling. It was decided to use two different strings of drill pipe, two instruments of radically different construction, and several methods of measuring rotation or orientation. The instruments were used simultaneously, that is, one was mounted directly below the other and rigidly attached to the lower extremity of the drill pipe. Readings by the instruments were made after each additional stand of pipe (88 feet in average length) was inserted in the well. Some of the surveys were made to a depth greater than 6,000 feet.

The inclination of the well from vertical was found to be a variable quantity and did not conform to a smooth curve. A drawing showing the full vertical section is too large for reproduction in this paper. A fair idea of the general downward course of the well is afforded by the following tabulated statement.

| *Depth (Feet)* | *Inclination from Vertical* |
|---|---|
| 300 | 0° 50′ |
| 600 | 3° 50′ |
| 900 | 3° 0′ |
| 1,200 | 1° 50′ |
| 1,500 | 3° 20′ |
| 1,800 | 7° 0′ |
| 2,100 | 2° 40′ |
| 2,400 | 4° 20′ |
| 2,700 | 5° 30′ |
| 3,000 | 6° 10′ |
| 3,300 | 5° 50′ |
| 3,600 | 8° 30′ |
| 3,900 | 9° 0′ |
| 4,200 | 7° 20′ |
| 4,500 | 10° 0′ |
| 4,800 | 10° 40′ |
| 5,100 | 9° 25′ |
| 5,400 | 10° 40′ |

The final result of all the tests is shown by Figure 1, which is in general self-explanatory. The letter *A* denotes results obtained by one instrument and *B* denotes the results obtained by the other instrument. The number accompanying each letter denotes the particular test; for example, *A-3* denotes the results obtained by the first instrument during test 3. The results of test 1 are omitted because it went only to a very shallow depth and disclosed little of importance.

A description of the instruments is not necessary at this time except to state that both had been extensively used and were of radically different construction. One made a continuous record on a strip of paper and the other made an intermittent record upon photographic film.

Test 2 used drill pipe having an outside diameter of 5½ inches and carrying an instrument container 7⅝ inches in diameter. Test 3 used drill pipe with an outside diameter of 4½ inches and carried an instrument container 5 inches in diameter. Test 4 used drill pipe 5½ inches in diameter with a 5-inch instrument case. The inside diameter of the well casing was 7¾ inches.

The variety of drill pipes used and the variation in the size of the instrument case gave opportunity to observe differences which might arise from the action of the pipe due to such causes as friction and elasticity. The use of two instruments operating simultaneously and under identical conditions demonstrated the amount of divergence due entirely to instrumental inaccuracies. Separate measurements of rotation of the drill pipe gave a basis for comparison of such methods.

There are three possible sources of errors in surveying bore holes by means of orientation from the surface, namely, instrumental inaccuracy,

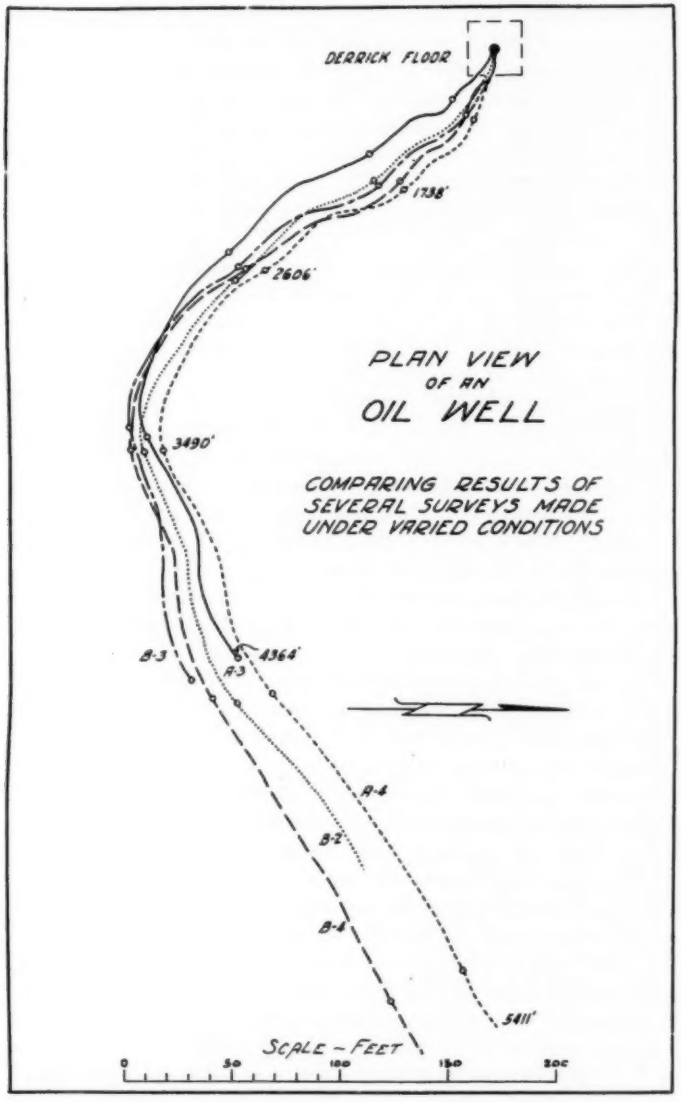
DERRICK FLOOR
1738'
2606'
PLAN VIEW
OF AN
OIL WELL
3490'
COMPARING RESULTS OF
SEVERAL SURVEYS MADE
UNDER VARIED CONDITIONS
B-3
A-3
4364'
A-4
B-2
B-4
5411'
SCALE - FEET
0
50
100
150
200

FIG. 1

errors in measurement of orientation, and erratic behavior of pipe. The aforementioned test was therefore conducted in such a manner as to appraise fairly the magnitude of error arising from each one or all of the sources which can affect the final result.

Instrumental inaccuracy must be reckoned with in all methods of surveying. It would be difficult, if not impossible, economically to construct an instrument, small enough to insert in a bore hole, which would be entirely free from error. However, it is possible to confine the error within narrow limits; furthermore, it is quite feasible to design an instrument which can be operated so as to neutralize the effect of its inaccuracy. The magnitude of discrepancy due entirely to instrumental inaccuracy is shown in Figure 1 by comparison of lines *A-4* and *B-4*, which are produced under conditions identical in all respects except the action of the instruments. Comparison of lines *A-3* and *B-3* also measures the limit of instrumental inaccuracy, and this pair of lines is separately shown in Figure 2 in order to give a clearer view of them.

For the purpose of deducting or segregating instrumental errors from the total error, a median or average line may be drawn between lines *A-4* and *B-4*. This median line contains only errors arising from the other two possible sources, rotation measurement and behavior of the pipe. A similar median between lines *A-3* and *B-3* serves the same purpose. Figure 3 shows the two median lines developed from tests 3 and 4 and indicates the limits of error arising from inaccurate measurement of orientation, plus any effect of erratic behavior of the drill pipe.

Consideration of the magnitude of errors arising from inaccurate measurement of pipe rotation is a broad subject, lying entirely within the scope of general surveying above the ground surface. The subject is adequately covered by many text books and need not be dealt with in this paper further than to state that it is simply a problem of accurately measuring angles in a horizontal plane. Probably the most accurate measurement of horizontal angles is that made in geodetic surveying, where a triangulation network is being established at the expenditure of almost unlimited time. In view of the narrow margin to which we have reduced errors, as shown by Figure 3, it is sufficient to state that the measurements of rotation made during the present tests were recognized as being not absolutely accurate. However, all the results here presented are on a uniform basis and are reasonably accurate. While an oil well is being surveyed, all of its drilling or producing operations are at a standstill; therefore, time must be economized by sacrificing absolute precision. The map shown in Figure 5 suggests the comparatively narrow

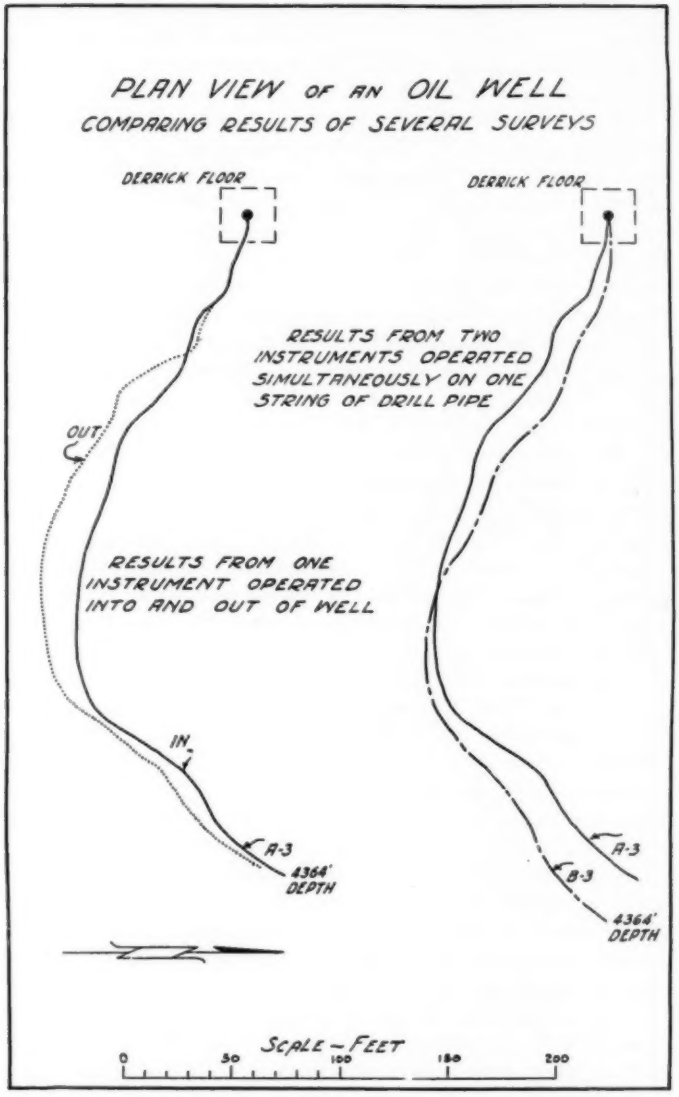
PLAN VIEW OF AN OIL WELL
COMPARING RESULTS OF SEVERAL SURVEYS
DERRICK FLOOR
DERRICK FLOOR
RESULTS FROM TWO INSTRUMENTS OPERATED SIMULTANEOUSLY ON ONE STRING OF DRILL PIPE
OUT
RESULTS FROM ONE INSTRUMENT OPERATED INTO AND OUT OF WELL
IN
A-3
4364' DEPTH
A-3
B-3
4364' DEPTH
SCALE - FEET
0
50
100
150
200

FIG. 2

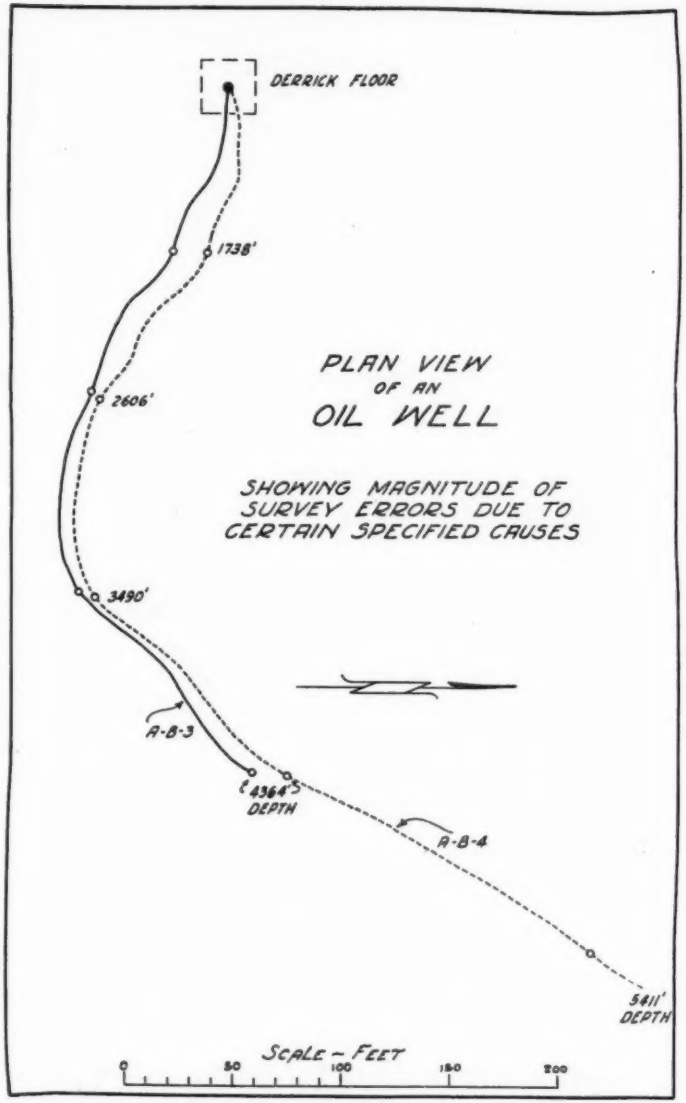
DERRICK FLOOR
1738'
2606'
3490'
PLAN VIEW
OF AN
OIL WELL
SHOWING MAGNITUDE OF
SURVEY ERRORS DUE TO
CERTAIN SPECIFIED CAUSES
A-B-3
4364'
DEPTH
A-B-4
5411'
DEPTH
SCALE - FEET
0
50
100
150
200

FIG. 3

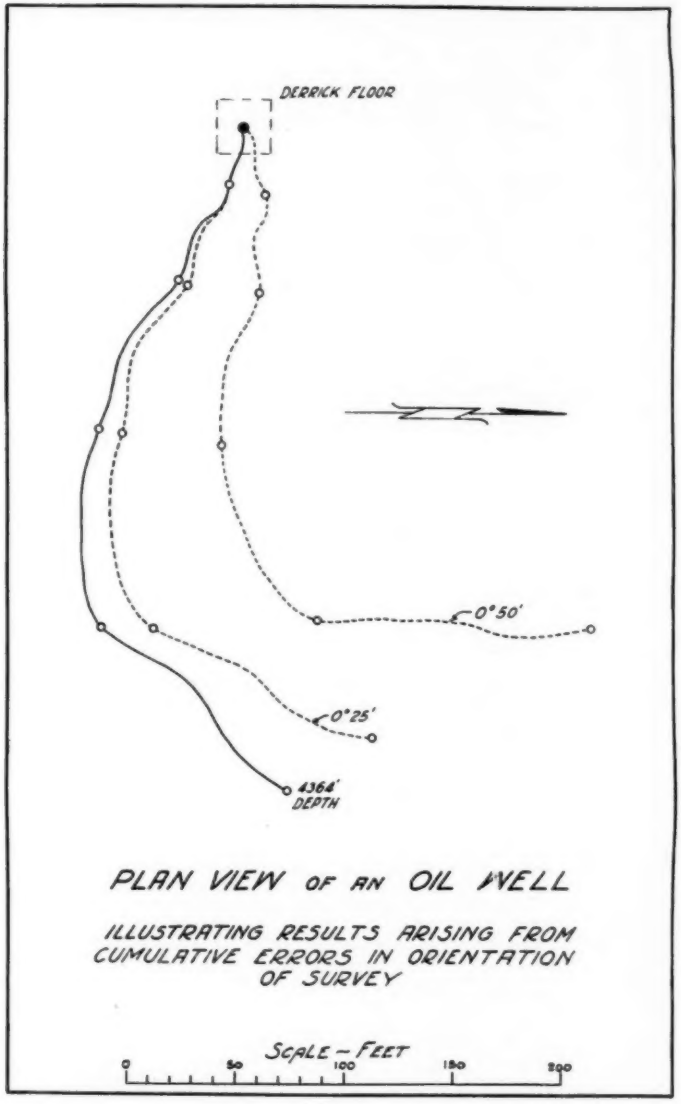
DERRICK FLOOR
0°50'
0°25'
4364'
DEPTH
PLAN VIEW OF AN OIL WELL
ILLUSTRATING RESULTS ARISING FROM CUMULATIVE ERRORS IN ORIENTATION OF SURVEY
SCALE – FEET
0
50
100
150
200

FIG. 4

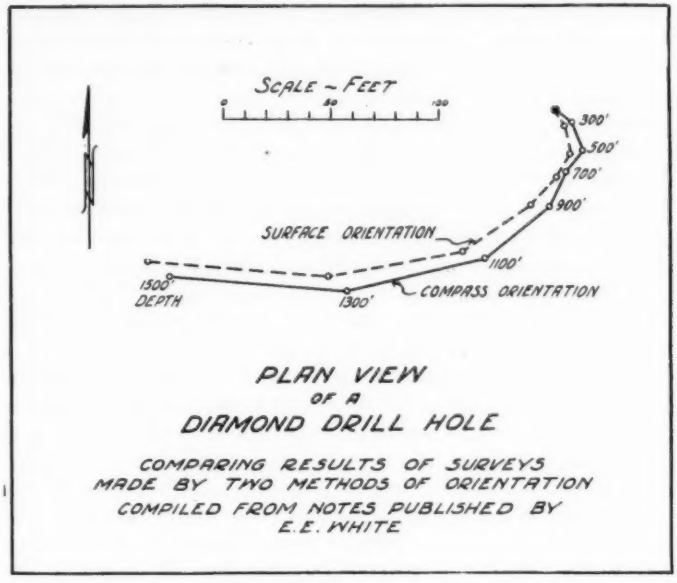


FIG. 5

limits to which compensating errors in orientation may extend. Figure 4 is presented to illustrate the very great errors which will follow the introduction of constant errors, each of seemingly insignificantly small dimensions, but repeated at each observation and always in the same direction.

In concluding the discussion of errors in measuring orientation, it may be said that the methods used during the series of tests and in common practice are sufficiently inaccurate to cover fully all the divergence shown in Figure 3 without searching for possible errors due to erratic behavior of the pipe. This conclusion is in accordance with that stated by Petersson.

Accuracy in determining vertical distances depends upon tape-line measurement of the drill pipe and instrumental measurement of vertical angles. The subject demands only brief mention, because correct results are readily obtained. There was a variation of less than 1 foot vertically between results of the two deepest surveys shown in Figure 1.

Although the previously outlined tests indicate that the drill pipe or tubing upon which an instrument is being operated is not the source of appreciable error, it is possible to present other more direct evidence to substantiate this conclusion.

In order to determine the effect of friction between the drill pipe and well casing, tests were made to determine how much twist could be put into the drill pipe. At test 3 with 5½-inch drill pipe, at a depth of 4,364 feet, the pipe was turned and the rotation measured both at the top and bottom of the string of pipe. When the instrument was first landed at the specified depth it was allowed ample time to record its position; then the rotary table on the derrick floor was turned almost half way round (161°), and the instrument was again allowed time to record its position. Next the pipe was lifted through the length of one stand of pipe (88 feet) and again lowered to the specified depth and time allowed for instrumental recording. The raising and lowering of the pipe was repeated several times. Comparison of measurements made at the derrick floor and at the instrument showed that when the pipe was first turned, without being raised and lowered, the instrument at the bottom turned only 137° while the top of the pipe turned 161°. In other words, a twist amounting to 24° was put in the pipe. After the pipe was raised and lowered once, the instrument showed that it had turned through the same angle as had the top of the pipe. In other words, the raising and lowering of the pipe had entirely freed it of twist. Each of the subsequent raising and lowering operations showed the same amount of rotation at both the top and bottom of the pipe. This result confirms the previously mentioned prediction made by White.

This test of rotation at the top and bottom of the pipe had previously been noticed many times by the writer where check surveys were made with a continuous recording instrument while it was being run into a well and while it was being withdrawn. Figure 2 shows the record of a check or round trip survey made during test 3. This round trip record represents ordinary practice during the course of routine surveying operations and it alone affords a basis of comparison almost as satisfactory and convincing as that produced by the more elaborate series of tests.

An example of the results obtained by a duplicate or round trip survey is shown by Figure 6. The survey went to a depth of 4,096 feet and involved 46 observations or readings, each way. The horizontal deflection was 235 feet. The vertical angles increased with considerable regularity from zero at the surface to 11½° at the bottom. While being

withdrawn from the well, the surveying instrument successively occupied each of the stations at which it had made its record while entering the well. It was therefore possible to make 46 comparisons of rotation of the pipe at both its upper and lower ends. The pipe used was 2-inch pump tubing, which is much more flexible than drill pipe. The pipe was, for convenience of measuring rotation, frequently turned at the derrick floor; consequently, the datum side of the instrument faced approximately in the same direction at each station. In other words, the instrument, on reaching a certain depth while coming out, faced within about 45° of the direction it had previously faced at the same depth when descending. During its whole downward course the instrument made two complete revolutions horizontally and did approximately the same while coming up. A comparison of all these readings showed identical action at both top and bottom of the pipe, with only such discrepancy as would be due to instrumental inaccuracy. The degree of coincidence of the two series of observations is shown by the courses plotted in Figure 6. The data were also compared in other ways and similar results obtained.

Another example of evidence furnished by a duplicated or round-trip survey is worth mentioning because physical conditions were considerably different, although the outcome was the same. A drilling well was surveyed to a depth of about 6,300 feet. Drill pipe with an outside diameter of 3½ inches was used, and casing with a diameter of 6⅝ inches. The hole was approximately vertical to a depth of about 4,200 feet, the inclination from the vertical being less than 3°. Within this distance the hole, as disclosed by a plan view, after describing a complete loop or spiral, having a diameter of approximately 40 feet, struck off in a comparatively constant direction. The part of the well below 4,200 feet, where the direction of its course was rather uniform, had a peculiar vertical profile, first flattening out to a vertical angle of about 14°, then straightening again until the inclination was only about 3°. While going into the well, the instrument turned around three times, due to the influence of the hoisting cables, and while coming out it completed four revolutions. Hence the instrument during its upward course was only once facing in the same direction that it had been while descending. Observations on the upward trip were discontinued at a depth of about 1,500 feet, making available 54 duplicated readings of inclination and direction. The horizontal discrepancy between the two surveys was 16 feet, and a comparison of readings, as in the preceding example, showed identical rotation of both ends of the drill pipe.

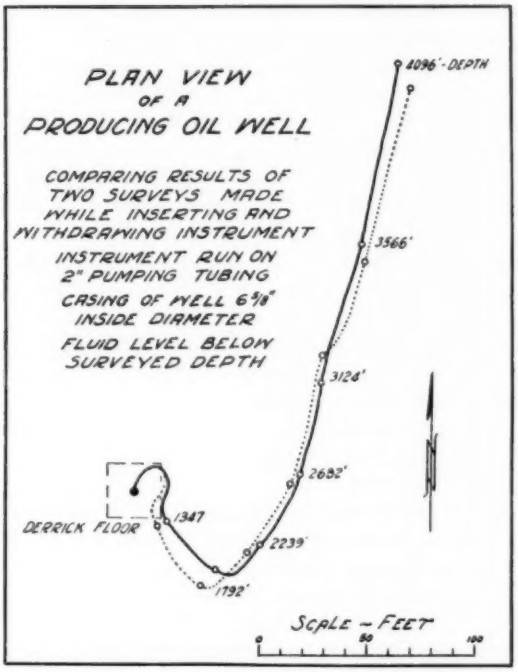


FIG. 6

It has been suggested that pipe would develop a twist simply by being hung up in a long string. The possibility of this has been tested and the test failed to develop any evidence to support the theory. If such an action did take place it would be counteracted in the course of ordinary surveying operations, which put full weight on the pipe before measuring for orientation.

In conclusion, it can be safely asserted that the surveying of bore holes by means of orientation from the surface is a method sufficiently accurate to meet the needs of the petroleum industry. As a corollary, it must be borne in mind that, as the entire operation is one involving precision, it assumes adequate equipment in the hands of a thoroughly informed and competent observer.

# CROOKED-HOLE PROBLEMS IN THE GULF COAST DISTRICT[1]

P. C. MURPHY[2] and SIDNEY A. JUDSON[3]
Houston, Texas

## ABSTRACT

Methods of surveying to determine the amount and direction of deviation from the vertical have been adopted in the Gulf Coast district during the last 18 months.

The amount of deviation is determined by using acid bottles or clinometers; of direction, by using a clinometer in combination with a magnetic compass, or by using the oriented drill-pipe method. The results of these last two methods are in approximate agreement.

The productive zone on the flanks of salt domes is so narrow that the position of the bottom of all wells should be known. Many operators survey all wells and correct those which are exceedingly crooked.

Well surveys aid the geologist to interpret correctly the complicated geologic structure, and to make new locations more accurately.

### ACKNOWLEDGMENTS

The writers thank the following companies for data used in this article: Humble Oil and Refining Company, Sun Oil Company, Mills Bennett Production Company, Humphreys Investment Company, and Humphreys Corporation.

### INTRODUCTION

The general practice of crooked-hole surveying in the Gulf Coast district was introduced in the latter part of 1928 by one of the operators, who used the method of obtaining deviations from the vertical by lowering into wells glass bottles partly filled with hydrofluoric acid, which method was adopted by several of the other companies. To increase the speed and accuracy of surveys, various types of clinometers were developed. A few operators also orient the drill pipe when clinometers are run into the hole, to determine the direction as well as the amount of deviation. One company successfully uses a recording magnetic compass for direction, combined with a mechanical device for determining deviation from the vertical. Another apparatus consists of a cylinder con-

[1]Read before the Association at the New Orleans meeting, March 21, 1930. Manuscript received by the editor, March 3, 1930.

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taining a magnetic compass floating in melted wax. The wax solidifies when left in the well a sufficient time, and holds the compass fixed in the wax. This method has not been extensively used.

### SURVEY METHODS SHOWING AMOUNT OF DEVIATION FROM THE VERTICAL

#### RECORDING FLUID LEVELS AND RECORDING CLINOMETERS

The method of survey with hydrofluoric-acid bottles, as used in the Gulf Coast district, is similar to that described by F. H. Lahee,[1] with the exception that in many wells the containers holding the bottles are run into the hole in special tool joints spaced at desired points in the drill pipe. The advantages of the acid-bottle method consist in its simplicity and positive action. A considerable disadvantage is the length of time the bottles must be left in the hole to etch the glass properly without permitting circulation of the mud or movement of the drill pipe. This leads to the danger of unconsolidated formations caving into the hole and necessitating a fishing job.

The instruments of the recording-clinometer type are generally equipped with timing devices to secure readings at regular intervals. They are placed in fluid-tight cylinders designed to resist the high pressures found in deep mud-laden holes, and are run into the hole on the end of the drill pipe and stopped for short periods of time at the depths at which the readings are desired. Ordinarily, the time between successive readings is 5 minutes. The advantage of this method over the acid-bottle method is that many successive readings are possible and a complete survey of the hole may be made with one run of the instrument. The short time that these instruments remain in one position greatly reduces the danger of the drill pipe becoming stuck. In addition, the connection with the bottom of the drill pipe is so designed that circulation is possible between readings, although in actual practice this is seldom required. These instruments may also be used in directional surveys in which the drill pipe is oriented.

### SURVEYS SHOWING DIRECTION AND AMOUNT OF DEVIATION FROM THE VERTICAL

#### RECORDING MAGNETIC COMPASS AND CLINOMETER

One company uses, in uncased holes, a compass that automatically records magnetic north and south at the same time that the inclination of the hole is registered by mechanical means. Only one reading can be taken in one run by each instrument, but several instruments can be run

[1] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 9 (September, 1929), p. 1095.

into the hole at the same time with their timing devices set to register at different times. The instruments may then be moved up or down between readings, and records from several depths may be obtained with one run. The instruments are enclosed in a fluid-tight, non-magnetic metal cylinder and are run on the bottom of the drill pipe, but separated from it by a spacing nipple of non-magnetic metal at least 10 feet in length. Readings with magnetic compasses taken with different instruments at the same depth ordinarily check each other for direction within 1° to 7° when the hole makes an inclination with the vertical exceeding 2°. The accuracy is not limited by the compass reading, but by the degree of precision of the clinometer.

### ORIENTING DRILL PIPE

Orienting has been used extensively in California and occasionally in the Mid-Continent. Recently a few operators are using it in the Gulf Coast district, some with satisfactory results. When orienting the drill pipe, coastal operators make use of various types of clinometers which record at regular time intervals. The clinometer is placed on the bottom of the drill pipe and the rotation of the drill pipe is measured as the instrument is lowered into the hole. The direction of the hole with relation to a north and south line can then be computed.

The accuracy of surveys with the oriented drill pipe has been questioned on account of supposed torque in the drill pipe as it is lowered into the hole. Table I compares typical examples of the directions obtained in uncased holes by orienting the drill pipe, with the directions recorded at approximately the same depths by the magnetic compass.

The wells listed in Table I are all on the flanks of salt domes and are reasonably straight. The four examples given in the table show an average difference of 0.25° per 100 feet. The directions obtained by the oriented drill-pipe method differ ordinarily slightly in a clockwise direction from those obtained with the magnetic compass. The compass readings are believed to be essentially accurate, and the results of orienting to be slightly in error, although not enough to detract from the practical value of the method. It should be noticed that several slightly different methods of orienting drill pipe are in use, and that the various mechanical conditions imposed by these several methods will probably produce results which vary slightly from one another. Accordingly, each method should be checked against compass readings to determine the individual factor of variation. The practice used here is to obtain compass records at least every 1,000 feet in an uncased hole and correct the oriented

TABLE I

COMPARISON OF ORIENTED DRILL-STEM SURVEYS WITH MAGNETIC-COMPASS READINGS

| | *Oriented Drill Pipe* | | *Magnetic Compass* | | *Variation of Oriented Method from Magnetic Compass* | | *Variation per 100 Feet* |
|---|---|---|---|---|---|---|---|
| *Well Number* | *Portion of Hole Included in Survey* | *Computed Direction of Bottom Reading* | *Depth in Feet* | *Recorded Direction* | *Amount in Degrees* | *Direction* | *Degrees* |
| 1 | Surface to 4,176 | N. 81½ W. | 4,195 | S. 84 W. | 14½ | Clock-wise | .34 |
| 1 | 4,176 to 5,112 | N. 88 W. | 5,179 | N. 88 W. | 0 | ..... | .00 |
| 2 | Surface to 2,208 | S. 64 E. | 2,207 | S. 70 E. | 6 | Clock-wise | .27 |
| 2 | 2,208 to 2,962 | S. 54 E. | 3,006 | S. 51 E. | 3 | Clock-wise | .39 |

survey to agree with the compass readings. As a compass of the ordinary type will not give correct readings in a hole that has been cased, the oriented drill-pipe method is used in such wells. The results are then corrected by using the factor of variation between oriented readings and magnetic compass records that have been previously determined by surveying many uncased wells by both methods.

## RESULTS OF SURVEYS

The first surveys of wells indicated to the operators that the average hole diverges considerably from the vertical and that the deflection of a hole 5,000 feet deep might be as much as 400 feet. Surveys with instruments which measured the amount, but not the direction, of deviation from the vertical, showed that the crooks ordinarily started at the point where the bit reached hard or broken formations dipping at steep angles just below soft formations. If thick shales were found beneath the hard formations, the holes continued to make an angle with the vertical, but ordinarily a smaller angle. A survey of the type mentioned showed whether the hole was straight or crooked, but it did not explain why adjoining wells with small angles of deviation would differ greatly in depth to the pay sand. The average range in width of production of a single member of a sand body on the flank of a dome is only 150 to 500 feet. In deep wells this narrow zone may be missed by wells making only small angles with the vertical, provided the direction of the well is directly toward or away from the dome.

It was first thought that most crooked holes went down dip and away from the salt dome, but the surveys indicated that this could not be true. Directional surveys were clearly needed, and a few operators adopted instruments and methods for this purpose. Both recording magnetic compasses and the oriented drill-pipe method were used for determining direction.

The directional surveys obtained by these methods show that crooked holes are about equally likely to go down dip away from the dome, up dip toward it, or clockwise along the periphery of the dome, or any combination of these three directions, but that few holes go in a counterclockwise direction along the flank of the dome. It is found that if a hole becomes very crooked and takes a certain direction, it ordinarily continues in that general direction as long as it keeps the same approximate angle of inclination. However, if such a hole tends to become vertical for a short distance and becomes crooked again, it ordinarily takes a different direction.

Figures 1 and 2 show surveys of typical flank wells on a salt dome by the oriented drill-pipe method, checked with a magnetic compass. Figure 3 is a survey of a typical well on a structural coastal field.

### DRILLING PRACTICE TO KEEP HOLES STRAIGHT

Current articles in oil-field technical publications give in detail the different methods used to drill holes as nearly straight as possible. The methods used in the Gulf Coast district are similar to those used in the oil fields in other parts of the United States having similar formations.

The permissible total deviation from the vertical in wells on the flanks of salt domes is governed principally by the width of the producing zone. Wells that make an average deviation of 4° are generally considered crooked, and a few operators endeavor to keep their wells within a 2° average.

The following list includes most of the methods generally used for the purpose of drilling straight holes.

1. Control of the weight applied to the bit.
2. Various types of reamers and guides used to keep the drill stem in the center of the hole for the first 100 feet above the bottom.
3. Use of large size drill pipe near the bottom to stiffen and give added weight to the drilling string near the bit.
4. Selection of different types of bits adaptable to the formations encountered at various depths.
5. Regulation of mud-pump pressures.

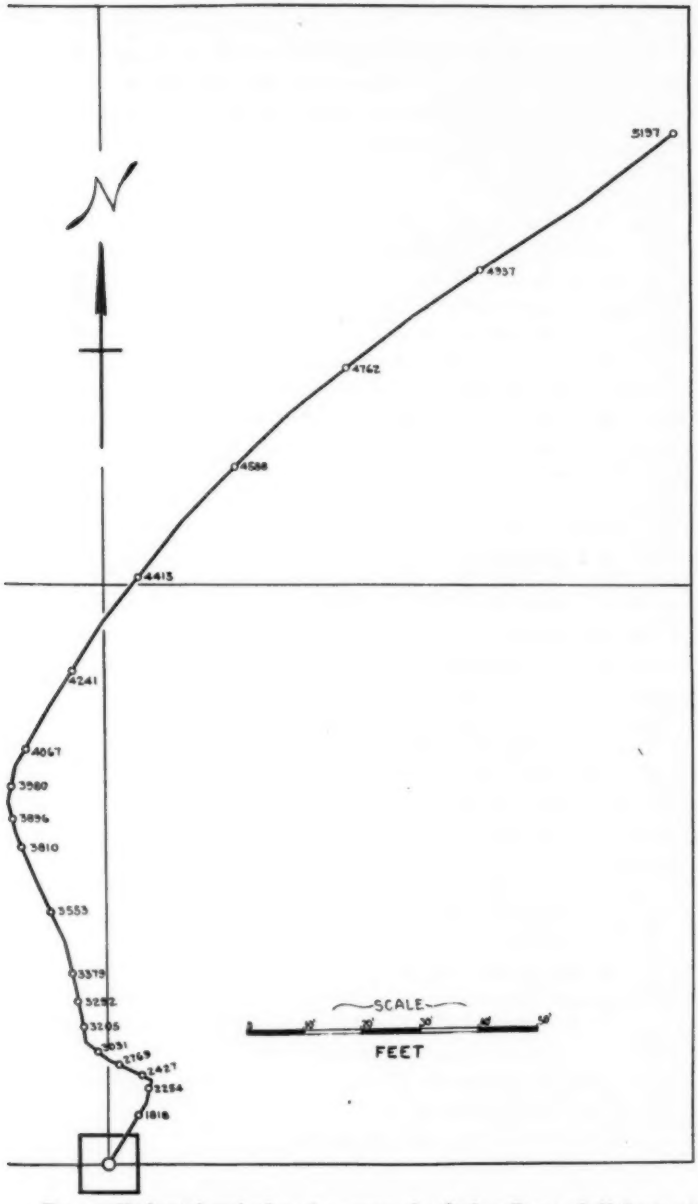


FIG. 1.—Horizontal projection of a survey of a flank well on a Gulf Coast salt dome. The oriented drill-pipe method was used and was checked for direction at the bottom with a magnetic compass.

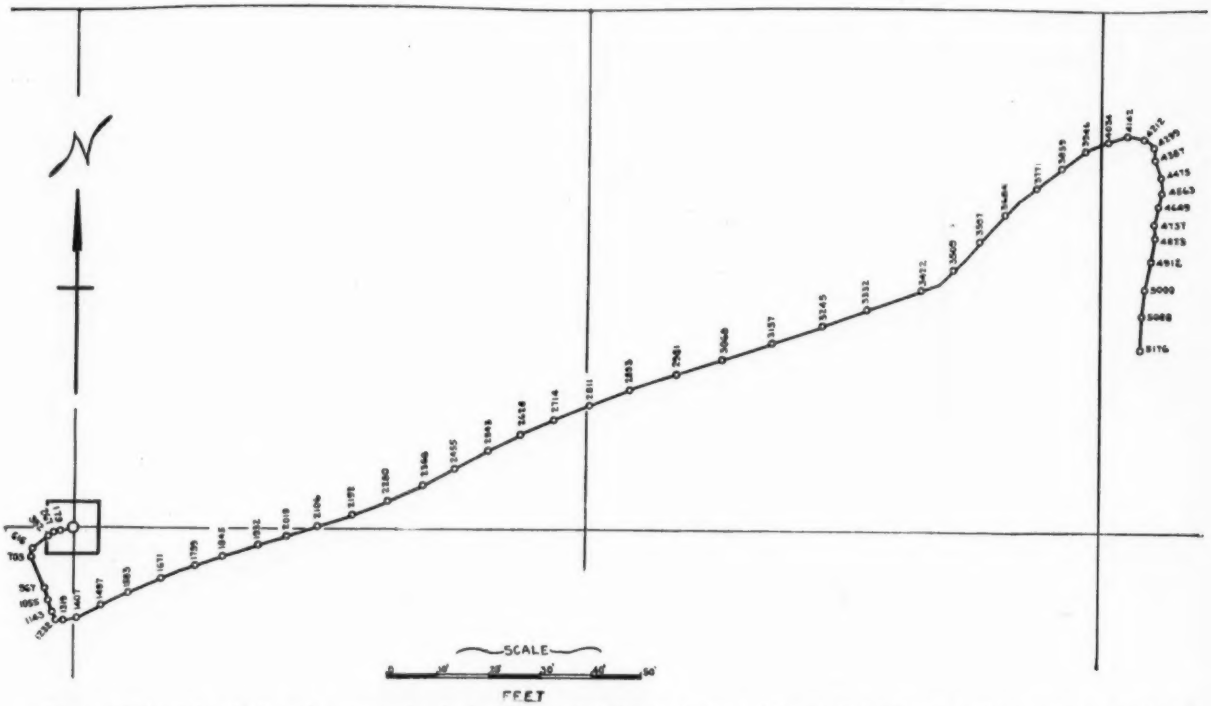


FIG. 2.—Horizontal projection of a survey of a flank well on a Gulf Coast salt dome. The oriented drill-pipe method was used and checked for direction at 2,832 feet with a magnetic compass.

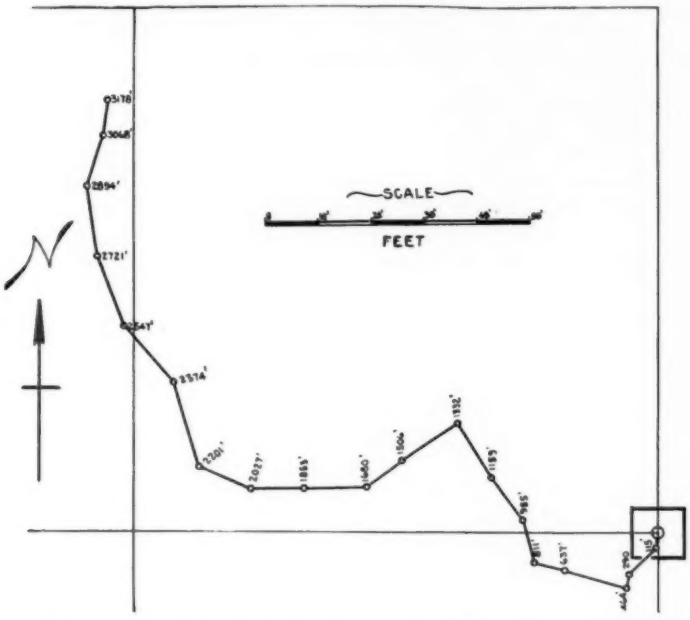


FIG. 3.—Horizontal projection of a survey of a well in a structural field in the Gulf Coast region. The oriented drill-pipe method was used.

## CORRECTING HOLES

The main purpose of drilling is to reach a productive sand rather than to drill a straight hole. The position and width of the oil zone can ordinarily be determined in producing areas by the surveys of near-by wells. If the survey shows a well to be crooked, particularly while yet at a shallow depth, it should be straightened if the crook is very large, or if it is in such a direction that the well would miss the productive sands. If the hole is only moderately crooked, however, and its direction is such that it will probably reach the sand in a productive position, drilling should be continued without re-drilling the hole to correct it.

On the assumption of a dome with flank production from a single sand body 300 feet wide with wells 5,000 feet deep, it will be seen that a well whose starting point at the surface is directly over the middle of the pay zone would miss production by 190 feet if the well goes directly away from the dome at an average angle of 4°. If it goes directly toward

the dome at the same angle, it would probably hit the intrusive salt body. If this same well, however, were to go directly along the periphery of the dome in either a clockwise or counter-clockwise direction, considered from the center of the dome, it would reach the sand at a productive level.

In correcting holes, several types of problems are found. The most common problem is that of straightening an uncased hole which is either very crooked or which, though only moderately crooked, would miss the producing horizon on account of the unfavorable direction in which the hole is going. The common method is to fill the hole with cement from the bottom to the point where it is desired to straighten it, or if the hole has been drilled much deeper than the crook, the top of a cement bridge is placed just above the bend. The hole is then re-drilled slowly, beginning at the top of the cement, and the new hole has a fair chance to be nearer the vertical than the previous hole.

It may become necessary to straighten a hole that is already cased, or to change the direction of a crooked hole that may be either cased or uncased so that it will go toward the productive sand. One method used is to orient a whipstock into the hole with its inclined side so directed that the bit will tend to sidetrack the hole in the desired direction as drilling proceeds. In the Gulf Coast district a few attempts have been made to use this method, but it has not been sufficiently developed for its merits to be determined under the conditions that exist here.

### COST OF SURVEYS AND DRILLING WELLS STRAIGHT

The cost of surveying wells consists of the actual cost of the surveys themselves plus the loss of drilling time while surveying.

The direct and indirect costs of making separate directional surveys with every 500 feet of additional hole amount approximately to 2 or 3 per cent of the total cost of a producing well. The increased cost due to the changes in drilling practice in order to keep a hole straight, and the cost of straightening a crooked hole, ordinarily range from 5 to 10 per cent of the total cost of the hole, depending upon the work required to correct possible crooks in the hole.

### ADVANTAGE OF STRAIGHT HOLES

Several advantages are gained in the Gulf Coast district by drilling holes straight. The principal one is in nearly eliminating dry holes in proved territory where the position of the narrow productive zone is known from surveys of previous wells. These surveys give the expected horizontal drift of a well between the surface of the ground and the pro-

ductive zone. With these data, well chosen locations for new wells can be made.

Directional surveys assist in the equal spacing of wells at the level of the producing sand. This gives a more thorough drainage, and accordingly a higher recovery per acre and per well. Formerly a dry hole would tend to stop drilling operations from extending around the periphery of a dome beyond the dry hole. A survey should be made of the dry hole, and if it is found that the hole is crooked and that the bottom is not in trend with the productive zone, drilling should be continued around the dome past the dry hole.

Straight holes reduce the number of fishing jobs and facilitate the recovery of the "fish." They also reduce the hazard of accidentally sidetracking the hole when reaming or fishing.

Lifting costs are lower if wells are straight, as there is less friction and accordingly an increase of pumping efficiency and longer life of equipment with straight holes as compared with crooked holes.

## SUMMARY

The results during the last 18 months of well surveying in the Gulf Coast district indicate that straight-hole practice tends to decrease the number of dry holes and the total number of wells necessary for proper drainage. It increases the average production per well and lowers the lifting costs. However, it adds 1-10 per cent to the drilling costs, but this is warranted by the advantages obtained. The speed and accuracy of the surveys are being rapidly improved, and it seems probable that the surveying of deep wells and the straightening of crooked holes will gradually become an established practice in the Gulf Coast district.

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## DISCUSSION

W. W. Scott, Houston, Texas: Murphy and Judson give an excellent summary of the status of the crooked-hole problem in the Gulf Coast district. The measurement of crooked holes and the problem of drilling straight holes has not been as actively followed in this district as in other places such as Oklahoma and California. However, the Gulf Coast district has kept pace with the progress in drilling straight holes and in the technique of detecting deviation. The matter of measuring crooked holes and drilling straight holes should be considered according to the following general types of work: (1) wildcat drilling, (2) restricted sand areas, and (3) drilling in fields of large areal extent.

*Wildcat drilling.*—All wildcat drilling is for the purpose of discovering oil or of obtaining geological information. In this type of work it is important that instruments be used that will measure the deflection of the hole correctly, and accurately locate the position of the bottom of the hole.

At present we do not have any instrument, with the possible exception of the outfit using the Sperry gyroscope, that will accurately determine the position of the bottom of the hole. With most instruments we are not sure of obtaining a reading that is representative of the deflection of a hole. I recall check runs made with an inclinometer, which employs the principle of photographing the meniscus of fluid in glass cells. This instrument is very accurate in measuring angles of deflection. The outfit was 6 inches in diameter and was run in a hole 9 ⅞ inches in diameter. Check runs at the same depth gave readings that varied as much as 2°. This was due to the fact that the instrument came to rest at different positions in the hole. If we desire to drill holes with less deflection than 2°, it is important that instruments and equipment be constructed that will give a reading which is representative of the angle of deflection of the hole.

*Restricted sand areas.*—In restricted sand areas such as are encountered in some Gulf Coast fields, it is important that measuring equipment be accurate and the hole be drilled with a deflection of not more than 2°, and this amount may be excessive for some fields. I do not think the equipment we are now using for orientation of the bottom of the hole is of sufficient accuracy. I refer to the magnetic compass and the orientation of the drill pipe described by Murphy and Judson.

*Production in large areas.*—In fields where production is not restricted to small areas, our present-day methods of drilling are satisfactory to finish wells where deflection will not be greater than 3° or 4°, and the instruments used for measuring are entirely satisfactory.

Much progress has been made during the past 2 years in mechanical methods for drilling straight holes and it has been demonstrated that with proper equipment and supervision straight holes can be drilled. Therefore, if proper equipment and methods of drilling are adopted, and the hole is checked for deflection as it is being made, there will be no necessity for well-measuring equipment to determine the exact position of the bottom of the hole. Most companies are now following this line of procedure.

In practice the program is to check the hole at fixed intervals so that serious deviation may be corrected before additional hole is made. Instruments used for this purpose are generally of the acid-bottle type. At present there are two makes of outfits which are designed for this work. The acid-bottle is placed in the so-called "Go-Devil" which is dropped through the drill pipe and comes to rest just above the bit. In a hole 3,500 feet deep it will take the "Go-Devil" about 6 or 7 minutes to reach bottom, and then it will require about 10 minutes for etching. This requires very little loss of time because these are usually run just previous to pulling out the drill stem to make a change in bits. It is the common practice to circulate for 15 or 20 minutes before pulling out, and during this operation circulation can be maintained. The acid bottle can be run during this period and requires very little additional time and no additional supervision.

The cost of measuring holes for crookedness as reported by Murphy and Judson appears to be high, although I have no definite information to dispute it. With present-day practice it occurs to me the wells can be measured at very little additional cost.

# GEOLOGICAL NOTES

## HOW OLD IS PETROLEUM GEOLOGY?

It is generally assumed that although a few geologists may have known, previous to the classic papers by the late I. C. White(37), that oil and gas fields ordinarily are related to anticlines, little effort was made to utilize this information. In a historical review of early theories regarding the origin and accumulation of oil(38), M. R. Campbell expresses astonishment that between the time of the drilling of the Drake well in 1859, and the paper by White in 1885, little was written by geologists and seemingly they were giving little thought to the subject. This surprise is natural, for it was during that period that the first great oil development occurred, with the opening of prolific fields not only in Pennsylvania, but also in Ohio, Virginia, New York, and Ontario, and with the excitement resultant upon these discoveries geologists must certainly have been stimulated to activity.

In an old volume of *Harper's New Monthly Magazine* for 1863(14) the writer happened recently to find an article which cast a somewhat different light on the geological activities of this period. Published anonymously, a reference in the text to "....my brother, Professor W. B. Rogers" indicates without doubt that it was written by Henry D. Rogers, who was the first state geologist of Pennsylvania, serving from 1836 to 1842, at which time the Survey was abolished.

The paper is entitled "Coal and Petroleum." After discussing in some detail the occurrence, nature, and origin of coal, Rogers turns his attention to "rock oil or petroleum," treating of it in similar manner. He concludes that the petroleum originated, not in the coal-bearing rocks, but more probably in black carbonaceous shales in the older rocks. He mentions specifically the Utica, Marcellus, and Genessee shales, pointing out that all are known to be bituminous at their outcrops, and that they appear to underlie the oil-bearing areas.

On page 262 appear the following significant paragraphs.

> There is indeed a law of gradation in the increase of the proportions of the hydrocarbons to the free or solid carbon, so universal and steady for change of locality, from the Southeast toward the Northwest for any traverse or section across the coal-fields, that it is practicable, within trivial limits of error,

to foretell the quantum of coke or gaseous matters the coal will yield by merely knowing what we may term its *geological longitude* from the line or axis of total debituminization or complete conversion into anthracite. And it is pertinent to our argument here to note, that not only must we traverse across the first fields a given distance of many miles, before we can meet in the coal beds themselves an assignable amount of the hydrogenous ingredients, but we must go a still further distance ere we encounter any marked indications or displays of the corresponding petroleums and carbureted hydrogens issuing from the general strata of the country. It is not in fact until we are almost half-way across the great Appalachian basin, in Pennsylvania and Virginia, where its *coals are already more than half* (italics mine. J. V. H.) endowed with the full share of their bituminous matters, that we fairly enter for the first time on the wide territory so marked by tracts or belts of gas springs and petroleum..... How unmistakably does this curious gradation indicate that the coal measures at least, and we can not but include the other formations underneath them, must all have undergone at some crisis, or during some long period, a widely diffused and graduated or locally modified and attempered distillation or expulsion of the gaseous ingredients of the carbonaceous strata! This change was an almost total discharge of the volatile matters along the eastern most heated and convulsed zone, with a less and less complete displacing of them from the coaly or carbonaceous beds in the regions further west.....

The hypothesis here suggested, namely, that the volatile hydrocarbons were distilled, as it were, from out the low-lying carbonaceous strata, into the pores and fissures of the over-resting ones, receives strong confirmation from the fact that the elsewhere bituminous shales of the Silurian and Devonian ages, deep under the coal, are altogether as much desiccated and debituminized everywhere in the districts contiguous to the anthracites as the coal beds themselves.....

Now the gradation in the quantity of the volatile matter in the coal is upon a general scale very nearly in proportion to a gradation which prevails in the openness or gentleness of these flexures of the crust. As already stated, the anthracite or non-bituminous coal belongs to the most disturbed ranges of the Allegheny chain, and the basins where it has the least amount of gas, seldom more than six per cent, are those where the strata show the boldest flexures and the greatest dislocations. The semi-bituminous coals are embraced in all the wider, deeper troughs, in the undulated crust, which hold a line more to the northwest, but parallel to the anthracitic ones. In them the volatile matter in the coal is generally from eighteen to twenty per cent., and the strata or coal measures, ranging along the southeast edge of the great table-land of the Allegheny Mountains, are nowhere undulated in steep flexures or intersected with dislocations of magnitude. Still further westward, where the last really conspicuous great anticlinal and synclinal flexures of mountain magnitude disappear, the coals contain of volatile matters as large an amount as thirty or thirty-five per cent. Westward again of this line, as along the borders of the beautiful Monongahela River, where the stratification is almost horizontal, and there is a nearly total absence of faults, the average is as high as forty per cent. While still further on toward the western border of the field, where the undulations in the rocks are extremely broad and gentle, the quan-

tity of volatile ingredients in the coal ascends to forty-five, and even to fifty per cent., varying with local circumstances.....

It appears obvious that in the foregoing paragraphs Rogers has outlined very clearly the fundamental principles of the carbon ratio theory, as stated in a much more complete manner by David White, in 1915. Some of the terms used are now obsolete, and the phraseology is rather involved, but of the meaning there can be no doubt.

But not only did this early worker recognize the relationship between carbon ratios and occurrence of oil. Witness the following extracts, written only four years after the completion of the Drake well.

....throughout all the western borders of the great coal-field, where the general flatness of the coal-rocks is only at wide intervals interrupted by narrow, but long and sometimes rather sharp anticlinal waves, the more copious emission of the rock-oil and the native gases is found to be chiefly restricted to the tracts occupied by the crests and sides of these local billows in the strata. It was long ago, before 1840, noted by my brother, Professor W. B. Rogers, in his geological survey of Virginia, and was observed and made known by myself in my own similar exploration of Pennsylvania, that nearly all the localities of abundant and comparatively permanent Artesian salt-wells or artificial brine-springs, with their almost invariable concomitants, the liquid and gaseous hydrocarbons, were situated upon, or nearly coincident with, the artificial archings of the strata. This was seen on the Kanawha by him, and on the tributary rivers of the Allegheny and Ohio by myself.....

....At an early period in the geological survey of Western Pennsylvania it was apparent that an anticlinal arching of the strata ranges under the localities which are now so rich in Petroleum on Oil Creek near the Allegheny River.

Rogers clearly had recognized the fact that the oil and gas springs, as well as the early oil fields, were almost invariably located on anticlines, and this only a few years after the first fields were opened. He was, it is true, rather mistaken according to present day concepts, regarding the manner in which the oil and gas formed and accumulated, having been led to the conclusion that great heat was necessary to the process, and that heated waters and steam were the transporting agents. But in the accuracy of his observations, and his conclusions drawn directly therefrom, one can find little to criticise.

The relationship between thermal springs and anticlines was brought out in a paper published by W. B. Rogers in 1843(1), having been read the preceding year. Careful reading of this paper fails to reveal any mention of the association of hydrocarbon gases with the waters of these springs. In the foregoing excerpt, H. D. Rogers says that the association of thermal springs, gas and oil springs, and anticlines was also "made

known by myself," but does not specify the manner nor the place. It is possible that he refers to some unpublished address on this or a related subject, inasmuch as in his writings he frequently refers to such addresses.

At a meeting of the Glasgow Philosophical Society on December 13, 1865, there was read a paper(26) entitled "On Petroleum," which was designated as having been sent from Boston by H. D. Rogers. He gives a rather long description of the oil wells, ventures some opinions as to the cause of flowing wells, quotes many figures on production of various fields, and describes the stratigraphy of the oil region, but for some reason says nothing definite regarding the origin or mode of accumulation. Suggesting that in the near future he will present a paper setting forth fully his views regarding the geology, he says:

> Meanwhile, permit me to recall to your notice what I put in print upon this topic in May, 1863, in the magazine called *Good Words*. You will find there a general synopsis of my views, but I trust to be able, at a not remote future day, to apply the generalizations there adventured to the elucidation of most of the phenomena descriptively set before you in the present essay.

Rogers' first published description of the gradation in volatile matter of coals and the explanation of the phenomena will be found in his "Geology of Pennsylvania"(4) on pages 808 and 995. Recognition of the relationship existing between this gradation and the occurrence of oil seems to have promptly followed the discovery of oil in Pennsylvania.

The papers of T. Sterry Hunt and E. B. Andrews (see bibliography) have been often quoted. Hunt seems to have recognized clearly the relationship of oil and anticlines; Andrews believed that the association was due to the presence of more faults along the crests of anticlines than in undisturbed strata. Both considered the presence of faults or fissures necessary to migration, but Hunt only seems to have recognized that pore spaces alone constituted a sufficient reservoir.

Meantime Sir William E. Logan(2, 11) recorded the association of oil springs with an anticlinal axis in Gaspé. Professor E. W. Evans(15) called attention to the fact that all the productive fields of West Virginia were located on a great anticline some 35 miles in length. Andrews, 5 years after his original paper, recognized(27) in 1866 that the fields of West Virginia and southern Ohio are located along the axis of an anticline, but still adhered to the view that the presence of fissures has been the dominant factor in localizing them.

In 1864, Alexander Winchell reported (seemingly for some commercial interest, as he was not at that time connected with the State

Survey) on an area in St. Clair County, Michigan, designated as the "Baker Tract, near Lakeport." This report is not available, but from a rather full abstract(23) a good idea of his views may be gained. The oil is considered to have been produced from black shales by slow distillation, and to have collected only where

> the shales are covered by an impervious layer, as of shale or plastic clay, the oil and gas elaborated are retained in the rocks, filling cavities by driving the water out by elastic pressure, and saturating porous strata embraced in the formation, or intervening between it and the impervious cover above.
>
> Slight undulations are liable to exist in all strata so nearly horizontal as those of the two peninsulas [presumably Michigan and Ontario]. The volatile emanations from the strata would therefore accumulate under the highest arches. Possibly one of these arches runs nearly north and south through the Canadian region, from Bothwell to Petrolia and beyond, while another underlies the district of petroleum manifestations (oil and gas in the drift) on the Michigan side of the river.
>
> In the transverse section across the strata, already referred to, an attempt has been made to show in what way the oil bearing rocks may rise in two or more gentle undulations, thus inducing the oil and gas to accumulate along geological axes, and become restricted to belts of country of limited width.

It has been stated repeatedly that the anticlinal theory was first formulated by Oldham[1] as a result of observations in Burma in 1855. Sidney Powers informs me that he has seen the original reference(3) from which these statements are derived, and has kindly furnished the following note.

> Thomas Oldham, in 1855, visited the Yenangyaung field of Burma and failed to recognize the anticline or the relationship between the presence of oil and geologic structure. A few days later he saw the anticline of the Tangyi hills and the oil seepages, and predicted, on the basis of seepages from the same geologic formation as at Yenangyaung, "that this petroleum will hereafter be found to exist in sufficient abundance to repay its extraction." This anticline is now the Yenangyat oil field, one of the most important in Burma.

It seems clear that this statement, even if it were available to geologists in this country, could not have been the germ of the anticlinal theory.

Another early publication, so far as known not listed in any bibliography, also deserves mention here because of the light which it sheds on the state of knowledge of petroleum geology at that time. This is a pamphlet of 16 pages, entitled "Report on the Petroleum Indications at Cheverie, Hants County, Nova Scotia. In Reference to the Probability of a Permanent Supply being Reached by Boring," by Henry Y.

[1] E. W. Shaw, *Econ. Geol.*, Vol. 13, p. 219.

Hind, M. A. It was published in Windsor, Nova Scotia, by C. E. DeWolfe in 1871. The writer's copy of this report was obtained through the kindness of H. A. Harley, of Windsor, Nova Scotia, son-in-law of Henry Hind.

The presence of oil in the cavities and joints of the gypsum and anhydrite quarried near Cheverie led to the organization of a company to search for a commercial supply, and Hind was commissioned to examine the area. Thus his report probably constitutes one of the earliest known efforts to select a drilling site by means of geological work. Fortunately the report is very complete, and gives an excellent idea of the state of knowledge at that time (1871). The following subjects are discussed.

1. Introduction
2. Sketch of the Geological Relations of Petroleum
3. Oil from Carboniferous Rocks
4. Oil from Devonian Rocks
5. Indications of the Presence of Oil in Underlying Strata
6. Conditions Required to Render a Flow of Oil Probable
7. Supposed Origin of Petroleum
8. Age of the Rocks at Cheverie
9. Structure of the Rocks at Cheverie
10. Evidences of the Existence of Oil at Cheverie
11. Probable Source of the Oil at Cheverie
12. Directions in Which Explorations Should be Made
13. Summary

Hind states on page 5,

....it must be borne in mind that the occurrence of oil in this Province in remunerative quantities is yet unknown; that the search for it involves a considerable outlay of capital; that its distribution and accumulation is governed by certain laws, *now tolerably well known;* and that if found in quantity it instantly becomes a source of wealth to the explorers, and may soon become a very important item in the mineral production of the province.

Again on page 7,

Where there are several anticlinal folds parallel to one another, the productive wells are always found on the axis, the intervening synclinals being barren, owing doubtless to the absence of fissures, the rocks in the *valley*, or synclinal fold, being more compressed.

He also quotes E. B. Andrews (*Amer. Jour. Sci.*, July, 1866) as authority for the statement that

By far the larger portion of the oil produced in West Virginia and Southern Ohio has been found along the axis of a well-marked anticlinal fold extending

from the borders of Southern Ohio forty miles or more into West Virginia, through Wood, Ritchie, and Wirt counties. Scarcely a barrel has been obtained in horizontal rocks, although hundreds of thousands of dollars have been expended in the search.

On page 9,

It is also to be observed that in some very important instances no surface indications were visible, and the finding of the oil was the result of borings for brine-springs, coal, etc., *or for oil, guided by the geological structure and age of the rocks*. Strata of a certain geological age, and of a particular horizon, and distinctly arranged in an Anticlinal form so that fissure receptacles may permit of the accumulation, being the only guides which led to very successful results.

After describing rather fully the stratigraphy, structure, and surface indications of oil at Cheverie, Hind concludes that the conditions necessary to accumulation are fulfilled, and suggests that test wells be drilled on certain anticlines in that area. He seems to have been fully cognizant of the importance of anticlinal structure, and of the necessity for the presence of an impervious shale or other sealing beds overlying the source rocks,[1] and to have recognized that seepages in indurated rocks are very unsafe guides to prospecting. He believed that fissures were necessary for accumulation, also that the oil was of local origin.

The foregoing quotations seem to justify the conclusion that within a few years after the drilling of the Drake well, in 1859, several geologists, and perhaps many, had recognized the fact that oil occurs chiefly on anticlines, that it should not be sought for in synclines nor in areas of undisturbed strata; that it probably originated in beds of bituminous shales rather than in coal beds, and that accumulation could take place under favorable structural conditions only where an impervious cover was present. In other words, their views in these respects would be quite orthodox to-day. Furthermore, it seems evident that even before 1871 geologists had been successfully engaged in the search for oil, and that this success was generally known to other geologists.

Evidence that the anticlinal theory not only had been in use, but that disputes had arisen over its validity, is furnished by a statement of one of its chief opponents. In his annual report for 1880, J. P. Lesley, then head of the Second Geological Survey of Pennsylvania, says(36):

The supposed connection of petroleum with anticlinal and synclinal axes, faults, crevices, cleavage planes, etc., is now a deservedly forgotten superstition. Geologists well acquainted with the oil regions never had the slightest faith

[1]Apparently first pointed out by Alexander Winchell, in 1865.

in it, and it maintains its standing in the popular fancy only by being fostered by self-assuming experts who were not experienced geologists.

The foregoing was written during the period (1875-84) in which I. C. White served as assistant on the Pennsylvania Survey. As Campbell has pointed out(38), none of the reports of the Lesley survey mentions the anticlinal theory, and all studiously avoid any consideration of the mode of accumulation.

In much of the Appalachian region where oil development was carried on during the early period considered, the folding is relatively pronounced, and most of the structure easily determined, hence a high degree of geological skill was unnecessary and no doubt many operators were able to get along without geological advice. Nevertheless, it seems extremely probable that many people were consciously using the geological data here set forth, and certainly known to most members of the profession at that time. It remained, however, for I. C. White to put in clear and concise form, with ample supporting evidence, the theory as it is now known, and furthermore to apply it widely and with undoubted success.

Rogers' early recognition of the carbon ratio theory, however, seems never to have been noted, and his idea remained unused. That this was due wholly to the fact of its anonymous publication in a non-scientific journal can not be questioned.

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March 14, 1930

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(Campbell points out that views here are those of Hunt, and apparently accepted by the Canadian Survey.)

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## ORDOVICIAN AGE OF THE PRODUCING HORIZON, BIG LAKE OIL FIELD, REAGAN COUNTY, TEXAS[1]

In March, 1929, cuttings below 7,000 feet from the Texon Oil and Land Company's University No. 1-B well, in the center of the Big Lake oil field, Reagan County, Texas, were made available to the writer through the kindness of the Bureau of Economic Geology, Austin, Texas.

Fossils of Pennsylvanian age characteristic of the upper part of the Atoka formation in Oklahoma, and of the Kickapoo Falls limestone member of the Millsap formation in Texas, were found between 7,000 and 8,295 feet.[2] Fossils were found in the cuttings between 8,295 and

[1]Published by permission of the Amerada Petroleum Corporation, Tulsa, Oklahoma. Since this note was written, it has been learned that Fred A. Bush, of the Sinclair Oil and Gas Company, Tulsa, found similar fossils and made approximately the same correlations at the time of the completion of the discovery well in November, 1928. It has also been learned that S. W. Lowman, of the Mid-Continent Petroleum Corporation, of Tulsa, has identified fossils characteristic of the Hunton limestone and Sylvan shale which he is publishing.

[2]Fossil lists were published by E. H. Sellards and Waldo Williams, "The University Deep Well in Reagan County, Texas," *University of Texas Bur. Econ. Geol. Bull. 2901* (1929), p. 190.

8,520 feet whose age could not be definitely identified without further study. Since the drilling of the Big Lake Oil Company's University No. 1-C, it is definitely determined that the lowest strata in both wells are of Silurian and Ordovician ages and that they probably represent formations equivalent in age to the Hunton limestone, Sylvan shale, Viola limestone, and Simpson formation of Oklahoma.

A list of the fossils in the discovery well, together with possible correlations, is here given.

| *Depth in Feet* | |
|---|---|
| 8,295-8,305 | White crystalline limestone, *Bairdia* sp., characteristic of the Hunton limestone of Oklahoma |
| 8,305-8,335 | Green shale, containing graptolites, characteristic of the Sylvan shale, identified by Fred A. Bush |
| 8,335-8,337 | Limestone lithologically resembling the Viola limestone |
| 8,364-8,372 | *Gastropoda* |
| 8,447-8,476 | Fauna characteristic of the Simpson formation.<br>*Eridoconcha oboloides* U & B<br>*Aparachites whitavesi* Jones<br>*Leperditia*<br>Fragments of *Bryozoa* cf.<br>*Rhynidictya*<br>Several *Ostrocoda*<br>Crinoids |
| 8,500-8,504 | *Aparachites whitavesi* Jones<br>Crinoids |
| 8,476-8,510 | Frosted free sand characteristic of the Simpson formation |
| 8,520-8,525 | (Total depth) Pay sand, cuttings not seen |

The age of the overlying formations in this field has been described by Ray V. Hennen.[1]

In the Big Lake Oil Company's University No. 1-C, the following correlations are made.

| *Depth in Feet* | |
|---|---|
| 8,341-8,346 | White crystalline limestone. *Bairdia* sp., *Kloedenella* sp., characteristic of the Hunton limestone |
| 8,346-8,370 | Green shale equivalent in age to the Sylvan shale |
| 8,552-8,563 | Shale and limestone, Simpson formation |

Attention is called to the discovery of oil-bearing Viola limestone in the South Bend oil field, southern Young County, Texas, at a depth of about 4,200 feet.[2]

[1] "Big Lake Oil Pool, Reagan County, Texas," *Structure of Typical American Oil Fields*, Vol. 2 (Amer. Assoc. Petrol. Geol., 1929), pp. 508-12.

[2] M. G. Cheney, "Pre-Mississippian Production in Texas," *Oil and Gas Jour.* (April 12, 1928), p. 31.

It is evident that the Silurian and Ordovician formations which crop out in the Arbuckle and Wichita Mountains of Oklahoma exist underground in parts of north-central and west Texas, and that they were originally continuous with the rocks of the same age which are now exposed in the Marathon uplift.

B. H. HARLTON

TULSA, OKLAHOMA
April 1, 1930

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## SILURIAN AT BIG LAKE[1]

E. O. Ulrich has maintained that the Richmond stage of the Cincinnatian is more properly a part of the Silurian than of the Ordovician. This classification is contrary to that of most other stratigraphers, but it seems to be the most natural classification to follow at Big Lake, Reagan County, Texas. In that field an apparently conformable series of Richmond-Alexandrian-Niagaran strata is separated by angular unconformities from the Pennsylvanian above and the Ordovician below.

The following table gives a classification and description of the Silurian formations at Big Lake. The thickness and character of the formations are described as they are found in the Big Lake Oil Company's University No. 3-C, and the depths at which they occur are appended for reference.

The Henryhouse and Chimneyhill limestones represent the Silurian part of the Hunton terrane of Oklahoma. The upper three (Devonian) formations have not yet been recognized at Big Lake. It is worthy of note that next to the Ordovician the Hunton is the largest pre-Pennsylvanian producing horizon in central Oklahoma. One well at Big Lake (the Big Lake Oil Company's University No. 2-C) is a commercial producer from the basal part of the Hunton; its production has increased from 575 to 650 barrels a day.

The thickness of the Silurian strata increases away from the top of the structure. In the discovery well, the Texon Oil and Land Company's University No. 1-B, only 10 feet of the basal Hunton limestone and 20 feet of upper Sylvan shale are present above the Ordovician (Chazy Simpson); whereas in the Big Lake Oil Company's University No. 1-C, which is 43 feet lower structurally on the top of the Sylvan than the discovery well, there is 10 feet of basal Hunton and 41 feet of Sylvan. There is 60 feet of strata of doubtful Ordovician age in this well, wedged between the Sylvan and strata identical with the

[1]Published by permission of the Mid-Continent Petroleum Corporation.

| | | |
|---|---|---|
| PENNSYLVANIAN | | |
| Des Moines | | Strawn black shales and dark brown cherty limestones |
| | | *Angular unconformity* |
| SILURIAN | | |
| Upper Niagaran | Hunton | Henryhouse limestone and light gray-green marl. Thickness, 25 feet (from 8,385 to 8,410 feet) |
| Lower Niagaran | Hunton | Upper Chimneyhill white and some pink crystalline limestone. Thickness 45 feet (from 8,410 to 8,455 feet) |
| Alexandrian | Hunton | Lower Chimneyhill glauconitic white crystalline limestone with basal oölitic member. Thickness, 15 feet (from 8,455 to 8,470 feet) |
| Richmond | Hunton | Sylvan green-gray to dark gray dolomitic shale. Thickness, 68 feet (from 8,470 to 8,538 feet) |
| | | *Angular unconformity* |
| ORDOVICIAN | | Gray, green-gray, bright green, reddish gray, and red-brown, highly calcareous to non-calcareous shales and thin white and light gray finely crystalline to dense fossiliferous limestones. Thickness? (from 8,538 to the last sample at 8,563 feet) |
| ORDOVICIAN | | |
| Chazy | | Simpson green and gray-green and gray fossiliferous shales and light gray and white fossiliferous limestones. These strata are not represented in the cuttings from University 3-C available at present. |

Chazy strata found in 1-B. In the Big Lake Oil Company's University No. 3-C, which is 142 feet lower structurally than the discovery well, there is 85 feet of Hunton limestone and 70 feet of Sylvan shale, which rests on strata that seem to be a younger part of the section found between the Sylvan shale and the Chazy Simpson in 1-C. It is known that Richmond strata occur in the Maravillas chert of the Marathon uplift. However, equivalents of the Sylvan shale and of the lower Niagaran and Alexandrian limestone have not been recognized in Texas outcrops.

S. W. LOWMAN

TULSA, OKLAHOMA
April 18, 1930

## MINNELUSA OF BLACK HILLS OF SOUTH DAKOTA

During the course of three summers spent in the Black Hills of South Dakota working upon the Mississippian formations, it became necessary for the writer to spend considerable time upon the stratigraphy and paleontology of the Minnelusa (Pennsylvanian) formation.

The results of this work have seemed of sufficient importance to warrant a short paper on the Minnelusa formation, as it is believed this formation will become of great importance in the drilling for oil and gas within the state of South Dakota, possibly not as a productive formation, but for purposes of subsurface correlation with areas east and west of the Black Hills.

The most important information dealing with the Minnelusa formation hitherto published is that contained in the well-known paper by Darton, "Geology and Water Resources of the Northern Black Hills"[1] and in the later paper by Darton and Sidney Paige, "The Central Black Hills."[2] In both papers the information about the formation is such as would be gathered in a rapid reconnaissance of the region; therefore, it is decidedly meager.

In working on the Mississippian of the Black Hills it was found that in order to determine the top of the Pahasapa formation it was necessary to make sections of the Minnelusa formation as well as the Pahasapa, and to collect and identify the fossils. Previously the paleontological knowledge concerning the Minnelusa was confined almost entirely to the basal beds and was so unsatisfactory that the general opinion held was that it might be either Pennsylvanian or Mississippian. A few fossils had been collected from the basal red shales and determined by Girty to be Pennsylvanian in age. These fossils came from the southern Black Hills near Loring Siding, and are listed in the Central Black Hills Folio.

The writer collected, in the same locality, during the summer of 1926 and again in the summer of 1928, and gathered from the red shales lying upon the Pahasapa limestone, the fossils here listed: *Spirifer cameratus*, *Spirifer rockymontanus*, *Spirifer boonensis*(?), *Composita subtilita*, *Marginifera muricata*, *Hustedia mormoni*, *Chonetes verneuiliana*, *Chonetes mesolobus*, *Chonetes granulifer*, *Derbya crassa*, *Productus* sp.(?), *Ambocoelia planiconvexa*, *Squamularia perplexa*, *Lophophyllum profundum*, *Eupachycrinus verrucosus* (plates and spines), *Archeocidaris* spine, *Cromyocrinus* n. sp., *Rhombopora lepidodendroides*, and *Fusulina* cf. *cylindrica*.

The evidence as presented by these fossils shows with little question that the basal beds of the Minnelusa formation are the equivalent of the Des Moines stage of the Carboniferous.

[1] *U. S. Geol. Survey Prof. Paper 65* (1909).

[2] *U. S. Geol. Survey Folio 219* (1925).

In addition to the fossils listed, a great many specimens of *Chaetetes milleporaceous* and numerous unidentified Bellerophons were collected from higher beds on the main road from Custer, South Dakota, to Newcastle, Wyoming. This locality is 21 miles west of Custer, near the foot-path to Jewel Cave.

The following section of the Minnelusa was made in the northern Black Hills.

SECTION OF THE MINNELUSA FORMATION IN BEAR BUTTE CANYON

(Just west of the county line, in Sec. 12, T. 5 N., R. 4 E.)

| *Bed Number* | | *Feet* |
|---|---|---|
| 40 | Sandstone, reddish to gray, covered with much slumped Opeche shale and slabs of Minnekahta limestone | 40 |
| 39 | Limestone, gray, rather soft, porous, tufa-like on surface | 12 |
| 38 | Sandstone, buff, red-stained | 15 |
| 37 | Limestone, gray, hard, fine-grained | 3 |
| 36 | Sandstone, grayish brown to buff, forming lower part of cliff | 40 |
| 35 | Sandstone, gray to brown, forming bold cliff face. Cross-bedded and weathering to rounded masses. Forms cliff face below upper massive sandstone | 85 |
| 34 | Talus-covered interval | 18 |
| 33 | Limestone, sandy, gray to reddish | 5 |
| 32 | Talus-covered interval | 20 |
| 31 | Sandstone, brownish, calcareous | 1 |
| 30 | Shale, red, fine-grained | 2 |
| 29 | Limestone, brown, sandy, thin-bedded, reddish stained | 3 |
| 28 | Sandstone, red, coarse-grained, stains rocks below and grades upward into overlying limestone. Not well exposed | 16 |
| 27 | Limestone, pinkish, hard, fine-grained, containing a large depauperate appearing fauna. Small trilobites (*Phillipsia*), *Aviculopecten*, *Nucula(?) Bellerophon*, et cetera, very plentiful | 3 |
| 26 | Limestone, gray, brown, fine-grained, sandy | 2 |
| 25 | Sandstone, brecciated, gray and red mottled. The breccia fragments are gray calcareous sandstone | 6 |
| 24 | Limestone, brown, sandy, fine-grained | 2 |
| 23 | Sandstone, gray, partly talus-covered | 10 |
| 22 | Limestone, gray externally, pinkish internally, fine-grained | 3 |
| 21 | Sandstone, pinkish, coarse, forming bold cliff face | 33 |
| 20 | Sandstone, brownish, coarse, brecciated in places | 2 |
| 19 | Limestone, sandy, cherty, fine-grained, gray | 5 |
| 18 | Sandstone, gray, fine-grained, weathering pinkish to reddish. Surface covered with small round nodules. Forms bold cliff face | 22 |
| 17 | Limestone, gray and brown, partly talus-covered, thin-bedded | 6 |
| 16 | Sandstone, gray to reddish, fine-grained | 12 |
| 15 | Limestone, gray to pink, sandy, fine-grained | 4 |
| 14 | Sandstone, fine-grained, pinkish, weathering to hard outcrops | 28 |
| 13 | Talus-covered interval | 5 |
| 12 | Limestone, gray, coarse-grained, sandy | 1 |
| 11 | Limestone, gray, fine-grained, in places cherty | 2 |
| 10 | Sandstone, pink with dark streaks, in places red, medium-grained | 4 |
| 9 | Limestone, gray to pinkish, fine-grained, contains calcite druses and iron crystals on exposed surfaces | 2 |

| | | |
|---|---|---|
| 8 | Limestone, pinkish, weathering gray, forming bold rounded exposure | 10 |
| 7 | Limestone, gray, fine-grained, with very thin sandy layers | 2 |
| 6 | Limestone, pinkish mottled, fine-grained, ledge-forming, partly talus-covered | 18 |
| 5 | Limestone, pinkish to white, with alternating thick and thin layers, contains plates and spines of echinids and small compositas | 12 |
| 4 | Talus-covered interval | 6 |
| 3 | Limestone, pinkish gray, fine-grained, pitted | 3 |
| 2 | Sandstone, white to pinkish, medium-grained | 10 |
| 1 | Shale, red, sandy, partly talus-covered, lying upon brecciated Pahasapa limestone | 20 |
| | Total | 493 |

The foregoing section was made within a few hundred feet of a similar section made by T. A. Jaggar, Jr.[1] In his section Jaggar has given a thickness of 450 feet, which is 43 feet less than that measured by the writer. It will be noticed, however, that he began his section at the base of the red shales lying upon the Pahasapa limestone and that in general they correspond throughout except that there are no fossils mentioned.

Within the sections as studied by the writer there are three recognizable fossil horizons. (1) The lower red shales which contain plentiful fossils of Des Moines age in the southern Black Hills. These shales have not been found to carry fossils in the northern hills, but as the beds are traceable from the southern hills to the northern hills, it is believed that careful examination will produce many specimens. (2) Approximately 50 feet above the base of the Minnelusa red shales is a well developed limestone carrying many plates and spines of echinids and casts of small compositas. So plentiful are these plates and spines that by dissolving the limestone in acid great quantities of the silicified remains may be obtained. This horizon is well defined throughout the Black Hills and can easily be recognized by the small white plates which weather out on exposed surfaces of the bed. This bed is especially well developed in Rapid Canyon, Bear Butte Canyon, Spearfish Canyon, and along the road 2 miles west of Willow Springs Ranger Station in Wyoming. (3) The bed numbered 27 in the section contains the most interesting and numerous variety of fossils. This is also a hitherto unrecognized horizon and contains great numbers of small pelecypods, a few trilobites, and a few gastropods. In general this fauna has the appearance of being depauperate. All are small; the average size of the pelecypods and trilobites is 10 millimeters. A few large gastropods are present and are well developed and of average size, but in general de-

[1] *Black Hills Folio 219*, p. 8.

pauperization is indicated. This bed has been traced over an area of more than 20 square miles in the northern Black Hills. It has not been recognized in the southern hills, as the writer was working on the Mississippian formations and gave but little attention to the Pennsylvanian. The best exposure of this bed is along the Deadwood-Spearfish road just west of the B. M. 4,362 and about 1 mile east of the old stage barn in T. 5 N., R. 3 E. Other localities are in Whitewood Canyon, southwest of Crook, and near the sawmill in Elk Canyon on the road to Crystal Cave.

The writer believes the bed containing the depauperate fauna will make an excellent, easily recognizable marker in well logs, and in view of the recent oil strike in the Black Hills, it is believed this paper is justified. It was the intention originally to include a list of the fossils from this bed and from other parts of the Minnelusa, but the press of work in connection with the paleontology of the Mississippian of that area has prevented such additional paleontological labors. It is hoped that such a publication can be made within a short time. All specimens from the three beds mentioned herein are at present in the repository at the State University of Iowa.

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BOX 337
FAIRVIEW, OKLAHOMA
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## EARLY PALEOZOIC STRATIGRAPHY OF WICHITA MOUNTAIN UPLIFT, OKLAHOMA[1]

*Introduction.*—Taff,[1] in 1904, recognized the presence of the Reagan sandstone, the Arbuckle limestone, and the Viola limestone in the Wichita Mountain uplift. The Simpson formation, and all Ordovician, Silurian, Devonian, and Mississippian formations known to crop out in the Arbuckle Mountains were not reported. However, the presence of the Bromide formation of the Simpson group in the middle hill of the group of the hills mapped as Viola, near Rainy Mountain Mission, has been known for some time. Howell[2] suspected the presence of Simpson

[1]Published by permission of the chief geologist of The Pure Oil Company.

J. A. Taff, "Preliminary Report on the Geology of the Arbuckle and Wichita Mountains," *U. S. Geol. Survey Prof. Paper 31* (1904).

[2]J. V. Howell, "Notes on the Pre-Permian Paleozoics of the Wichita Mountain Area," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 6, No. 5 (September-October, 1922), pp. 413-25.

underground in the Wichita area, but did not have the necessary information to establish its presence or the presence of the Hunton, Sylvan, and Woodford formations. Recent drilling has revealed the presence of the Simpson group, Sylvan shale, Hunton group, and Woodford shale beneath the covering of Red-beds. In the following pages a complete lithologic description of the pre-Caney, post-Canadian formations as revealed by the drill is given. Identification of formations is based on lithology, sequence of beds, and in some instances paleontology. The Arbuckle and Reagan formations are not considered, though they have been found in many wells. The Caney shale has not as yet been recognized. The Pennsylvanian formations which come into the section off the flanks of the uplift are not treated herein. Part of the writer's observations have been published by Becker.[1]

*Geologic section.*—The accompanying section of pre-Caney, post-Canadian rocks is based on the microscopic examination of well cuttings. Bed 64 was found in the Sossaman Thompson No. 1, NW. ¼, SW. ¼, Sec. 11, T. 6 N., R. 17 W., from 750 feet to 930 feet. Beds 41 to 63, inclusive, were found in the Johnson and McDowell Wedle No. 1, SW. ¼, NE. ¼, Sec. 6, T. 6 N., R. 15 W., from 660 to 2,490 feet. Beds 1 to 40, inclusive, were found in the Tah-lah-ta-tite No. 1, NE. ¼, SE. ¼, SW. ¼, Sec. 13, T. 7 N., R. 16 W., from 1,710 to 3,222 feet. Early Paleozoic beds were found in several other wells, but these three wells penetrated the greatest amount of section, and cuttings from them were well kept. The thickness given for each bed may or may not be the true thickness of the bed, inasmuch as the inclination of the strata is unknown. It is highly probable that the strata are inclined in the area, and that the thicknesses are excessive.

The writer believes that the section may be used as a standard section to which to tie correlations in the Wichita Mountain area. In several places wells have drilled out of the Red-beds into different parts of the Simpson formation, which could satisfactorily be tied into the accompanying section by a study of the lithology and paleontology. The Simpson section given is probably not complete. In two wells a few hundred feet of Simpson shales and limestones were found which seem to be older than bed 1, but the correlations are too indefinite to merit the inclusions of these beds in the accompanying section.

[1]Clyde M. Becker, "Structure and Stratigraphy of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 1 (January, 1930), pp. 37-56.

| | | |
|---|---|---|
| | *Woodford Shale* | *Feet* |
| 64 | Shale; black, hard, somewhat pyritic and cherty; contains *Sporangites huronense;* top and bottom contacts not seen; maximum thickness noted | 180 |
| | *Hunton group* | |
| 63 | Limestone; gray, rather dense-textured, very sparingly fossiliferous | 315 |
| 62 | Magnesian limestone; brown, finely crystalline | 25 |
| 61 | Limestone; gray, dense; very sparingly fossiliferous | 30 |
| 60 | Magnesian limestone; brown, granular-textured | 10 |
| 59 | Limestone; gray, fine-grained, rather dense; contains a few fossils found elsewhere in the Henryhouse(?) formation of the Hunton group | 32 |
| 58 | Limestone; white, coarsely crystalline | 18 |
| 57 | Limestone; white, extremely cherty | 135 |
| 56 | Limestone; white, coarsely crystalline | 15 |
| 55 | Magnesian limestone; brown, cherty | 23 |
| 54 | Limestone; gray, dense-textured, slightly oölitic; contains some oölitic chert | 2 |
| | *Sylvan shale* | |
| 53 | Shale; gray, hard, non-calcareous, pyritic | 125 |
| 52 | Shale; dark, dolomitic, slightly pyritic | 40 |
| 51 | Limy shale; dark, slightly pyritic | 80 |
| | *Fernvale limestone* | |
| 50 | Magnesian limestone; brown, fine-grained, cherty | 12 |
| 49 | Limestone; white, coarsely crystalline | 23 |
| | *Viola limestone* | |
| 48 | Limestone; white to brown, crystalline to fine-grained | 23 |
| 47 | Limestone; like bed 48, but very cherty | 7 |
| 46 | Limestone; like bed 48 | 15 |
| 45 | Dolomitic limestone; dark, cherty | 30 |
| 44 | No record, probably limestone | 135 |
| 43 | Limestone; like bed 48 | 240 |
| 42 | Limestone; like bed 48, but slightly cherty | 45 |
| 41 | Limestone and magnesian limestone; brown, dense to finely crystalline; some layers very cherty | 450 |
| | *Simpson group* | |
| 40 | Limestone; brownish gray, dense | 10 |
| 39 | Limestone; brownish gray, dense, with partings of green shale; contains such characteristic Black River fossils as *Pachydictya foliata* | 20 |
| 38 | Limestone; like bed 39, but more crystalline | 15 |
| 37 | Shale; green, hard, with thin beds of sand and limestone | 70 |
| 36 | Sand; white, fine-grained; grains well rounded and frosted | 15 |
| 35 | Sandy shale; green, very sandy | 45 |
| 34 | Sand; white, loose | 10 |
| 33 | Shale; green | 5 |
| 32 | Sand; white, fine-grained, loose | 15 |
| 31 | Sandy shale; green, with beds of very fine-grained tight sand | 5 |
| 30 | Sand; white, fine-grained, loose | 32 |
| 29 | Sandy shale; green, very sandy | 10 |
| 28 | Sand; white, fine-grained, loose | 15 |
| 27 | Shale; green | 5 |
| 26 | Sand; white, medium-grained, loose | 69 |
| 25 | Sand; white, tightly cemented | 15 |
| 24 | Sand; white, loose, with beds of green shale | 17 |
| 23 | Shale; greenish, hard, practically non-sandy and non-calcareous | 127 |

| | | |
|---|---|---|
| 22 | Shale; greenish, with beds of limestone | 30 |
| 21 | Dolomitic limestone; light gray, slightly sandy | 5 |
| 20 | Shale; greenish | 40 |
| 19 | Shale; greenish, beds of crystalline, sandy limestone | 10 |
| 18 | Shale; greenish, slightly sandy | 18 |
| 17 | Shale; greenish, with beds of crystalline ostracodal limestone | 15 |
| 16 | Shale and limestone; interbedded, full of ostracods | 20 |
| 15 | Shale; greenish, with a few beds of fine-grained granular limestone | 15 |
| 14 | Limestone; white, fine-grained, granular | 20 |
| 13 | Shale and limestone; greenish shale and interbedded limestone, many beds of which are full of ostracods | 95 |
| 12 | Shale; greenish, hard | 42 |
| 11 | Limestone; white to light gray, finely granular to crystalline, mottled, sparingly fossiliferous | 70 |
| 10 | Shale; greenish, hard | 9 |
| 9 | Limestone; white to gray, mottled, crystalline to granular but mostly granular, slightly fossiliferous in basal 16 feet | 67 |
| 8 | Limestone; brownish gray, finely granular | 40 |
| 7 | Shale; dark greenish | 19 |
| 6 | Shale and limestone; greenish shale and fine-grained limestone interbedded | 50 |
| 5 | Sand; light gray, calcareous, argillaceous, impure, tightly cemented | 40 |
| 4 | Shale and limestone; greenish shale and light gray impure crystalline limestone interbedded; some beds quite fossiliferous | 30 |
| 3 | Limestone; light gray to brownish gray, fine to coarse-grained, impure, crystalline; probably contains some shale beds; somewhat fossiliferous | 200 |
| 2 | Limestone and shale; limestone like bed 3 interbedded with greenish shale; somewhat fossiliferous | 50 |
| 1 | Limestone; white to brownish gray, crystalline to fine-grained; somewhat fossiliferous | 137 |

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TULSA, OKLAHOMA
April 7, 1930

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## DISCOLORATION OF SEDIMENTS BY BACTERIA[1]

Black shales, because of their importance as source beds, have attracted considerable attention from petroleum geologists. Much light has been thrown on the origin of these deposits by recent studies as to the nature and origin of the coloring constituents of black muds now accumulating. In the muds of the Baltic Sea, Chesapeake Bay, and other regions, disseminated carbonaceous material and black ferrous sulphide have been noticed. Bacterial action undoubtedly is an important factor in producing these constituents.

The writers wish, briefly, to call attention to the results of preliminary experiments, in which a type of pigment caused by bacterial action produces dark sediments in the laboratory, and to suggest that a similar pigment may exist in black muds. It was found that certain

[1]Read before the Association at the San Francisco meeting, March 22, 1928
Manuscript received by the editor, April 9, 1930.

samples of soil darkened when permitted to stand several days in a weak salt solution, but remained unchanged when placed in fresh water. A series of experiments carried out in ordinary test tubes disclosed the following facts.

1. The darkening of the sediment was due to a pigment produced by bacterial action on organic matter, either animal or vegetable.

2. The source of the bacteria was the soil itself, but darkening occurred only when conditions were favorable for their rapid growth.

3. The conditions favorable for rapid growth were an excess of organic material, the presence of a weak salt solution, and a temperature approximately equivalent to blood heat.

The pigment is a finely disseminated, perhaps colloidal, material secreted by the bacteria during metabolism. Its chemical composition has not yet been determined definitely, but it seemingly is a humic-acid derivative. It exists only within the limits of the bacterial colony. The darkening commences as a series of isolated black specks. As colony growth progresses, each speck spreads out as a circular mass, and adjoining masses eventually unite.

In these experiments äerobic bacteria seemed to be the important factors. An unidentified species of *Spirillum* was found to be abundant where action was taking place. However, it should be emphasized that such pigments are probably not produced by any one species or group of bacteria, but may be secreted by a variety of äerobic, anäerobic, and facultative anäerobic forms. The bacterial action was accompanied by the emission of a gas having an odor resenbling that of a salt marsh. Chemical tests indicated the absence of nitrites, nitrates, and hydrogen sulphide.

The sediment employed in the experimental work is a light brownish gray residual soil from the Colorado School of Mines campus. It is derived from the underlying Arapahoe (Eocene) formation, and has accumulated since the formation of a Pleistocene erosion terrace. Slightly decayed leaves, roots, and twigs of small plants are plentiful in it. Under the microscope, the sediment is seen to be essentially a sandy silt, though a small percentage of clayey material may be eliminated by washing. The subangular quartz grains vary from .005 to .05 millimeters in diameter, the small sizes predominating. In places, groups of grains are loosely cemented by a thin coating of nearly white to pale red iron-stain. A distinct effervescence in acid indicates the presence of small quantities of carbonates.

No plant matter was employed, other than that in the soil itself. The animal matter used was egg albumen.

*Summary.*—A black pigment, secreted as a result of metabolic processes of bacteria, is capable of producing dark color in sediments in laboratory experiments. The same type of pigment may be a coloring constituent in some dark muds and shales. Further study is necessary to determine its geologic importance.

In the experiments referred to, the stains produced disappear upon the drying of the sediments, but it is possible that with age the staining material may be converted to some more permanent pigment. In any event the phenomenon is very interesting in that it suggests that bacterial action may be more important than is generally realized in the production of the dark staining material of sediments.

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## STRUCTURE OF TYPICAL AMERICAN OIL FIELDS[1]

Attention is invited to the broader aspects of the relation of petroleum accumulation to structure as related (1) to reservoir rocks and (2) to regional sedimentation and tectonics. A comprehensive picture of all the geologic conditions is as necessary to an understanding of petroleum accumulation to-day as was a mere general conception of the structural theory of I. C. White ten years ago, and the importance of comprehensive study will steadily increase.

A few speculations are given in the following paragraphs in order to be suggestive, not dogmatic. The most important of these concern folding contemporaneous with the filling of geosynclinal prisms of accumulation, and refolding along predetermined axes, the location of major lines of folding, especially of other beds in shallow geosynclinal basins, being controlled by lines of weakness in the basement rocks.

The primary control of accumulation in many areas is the physical character of the reservoir rock, which determines the type of structural control and the relations of oil, gas, and water. Sandstones, limestones, dolomites, and cherts are the dominant reservoir rocks. A reservoir rock may be widespread with structural accumulation anticlinal where con-

[1]Prefatory note, reprinted from *Structure of Typical American Oil Fields*, Vol. II (Amer. Assoc. Petrol. Geol., 1929), with omission of the first paragraph and with slight modifications.

trolled by the presence of water, or synclinal where water is absent. In lenticular porous sandstones, however, accumulation may be determined by the shape of the lens or by hydrostatic equilibrium, or by both; therefore, the oil may occur on monoclinal or homoclinal structure. Limestones and similar rocks act as reservoirs in anticlinal folds and buried hills only where porous, and this porosity is in most areas due to solution at unconformities or to dolomitization. Fracture zones form reservoirs in limestone and shale irrespective of local structure. Under hydraulic head the upthrown side of normal faults, especially the basinward side, may act as a reservoir for oil, whereas the downthrown side rarely acts as a reservoir except where the faulting took place after accumulation. Readjustment of the oil-water level in faulted anticlinal folds in which accumulation preceded faulting is dependent on the degree of stagnation of the water. Accumulation of oil in overthrust faults is in most places controlled by hydraulic head. Discordant igneous intrusions rarely, if ever, trap oil.

Oil fields are commonly developed in sedimentary rocks deposited in epeiric or mediterranean seas near the edges of geosynclines, but not where the folding or faulting is intense; they occur also within, and even in the centers of, such basins and major geosynclines. But the apparent total absence of oil from large parts of certain basins, irrespective of proved continuity of reservoir conditions, and of continuity of geologic structure extending out from oil fields, is not understood and is a problem of oil genesis or migration, rather than of structure.

Oil and gas seepages have led to initial discovery of many oil fields. After the introduction of geology, visible folds of anticlinal type and, later, similar folds discovered by subsurface studies based on well logs, were drilled with great success. For a decade the drill and seepages, rather than geology, pointed the way to fields in the gently folded rocks in the centers of shallow geosynclines and in smaller intra-continental basins. In recent years a better comprehension of the basic principles of geology as related to petroleum together with intensive scientific exploration has proved the importance of such areas and has already led to the discovery of some of the most important oil fields of the world.

Deductions from studies in the Appalachian Mountains and from the experimental production of folds of Appalachian type have dominated the conception of folding and of mountain-building in the United States. Like the Neptunian doctrines of Abraham Gottlob Werner, these conceptions stood unchallenged for many years. Isostasy and petroleum geology have brought into the science modified views and have shown the

true relation of a thin veneer of incompetent sediments to the underlying vast thickness of competent rocks. Structure in the sedimentary rocks, and especially in the thin sheets over many geosynclines, is determined by forces acting in the underlying basement complex. Anticlines, buried hills, faults, and even synclines underground, and especially in or near the basement rocks, may be overlain by entirely different types of structure—by anticlines or salt domes or faults with an entirely different strike or by homoclines. In gently folded rocks the structure underground is more sharply folded and covers less area than at the surface.

Earth movements which initiate epi-continental seas and geosynclines of deposition, and complete geanticlines of compression, act slowly through long periods of time with spasmodic stillstands and slight positive movements which cause disconformities, unconformities, lines of weakness, and incipient lines of folding. In some geosynclines of deposition the loci of the major folds and lines of folding are determined by buried topography or structure or fragmentation in the basement rocks and superimposed folding began during or after the deposition of the lower part of the ultimate sedimentary column, and in the time scale take place several geologic periods before ultimate cessation of sedimentation. These folds are rejuvenated from time to time so that the sedimentary sections in them show initial thinning. Between these primary folds secondary folds and lines of folding are formed later.

Translated into factors of oil accumulation, the time of formation of anticlines and synclines and the time of stillstands and of aerial exposure of newly deposited sediments become very important because at these times the lithological composition and porosity of sedimentary rocks were modified locally. Sand lenses are temporary shallow-water or shore phenomena and may be found far from the original limits of sedimentary basins. Widespread porous limestones may owe their porosity to temporary land conditions and to solution by surface and underground waters before complete lithification of the prism of sediments. Dolomite is evidently a later secondary alteration product of limestone after lithification. Local porosity in limestones may be due to coral or algal reefs which may form interbasin bars of great lineal extent bounded on either side by rocks of different lithological composition.

Anticlines and synclines formed during the last folding of the geosynclinal basin may produce oil. But many of the largest and most prolific oil fields of the world are on primary anticlines of early formation which were refolded once or several times and which show structural dis-

cordance not traceable in adjacent synclines. Such primary anticlines form the buried structures, buried hills, and buried ridges which were recognized for the first time thirteen years ago. The older, partly truncated rocks in them may or may not produce oil or may not be within reach of the drill. The structure of these older rocks may even be synclinal below oil-bearing anticlines of later generation. Entire anticlinal ridges of secondary folding may be barren although primary anticlines on either side produce oil. These are reasons for believing that one of the prerequisites for oil accumulation in some geological provinces is anticlinal structure which was formed concomitantly with deposition, as shown by initial thinning in the stratigraphic section; in other words, that the generation and migration of the oil antedated the final folding.

Structure has therefore assumed a new significance in the quest for oil. An anticline in a petroliferous province is not the sole desideratum. Anticlines may be barren and synclines productive. Homoclinal dip may be the proper type of structure. Where accumulation is anticlinal, the history of sedimentation and of folding, as revealed in large extent by subsurface studies, will in many cases differentiate petroliferous and barren anticlines.

Geological thought is evolving rapidly. The contribution of petroleum geology to knowledge of structure, stratigraphy, and paleontology is becoming ever more important. Research now accompanies and follows observation. Comprehension of the nature and origin of folding has been hampered by lack of knowledge of the third dimension. Well data are supplying this information. *Structure of Typical American Oil Fields* is, therefore, a contribution to research. May it stimulate a better understanding of structural geology as well as aid in the discovery of new oil fields the world over.

SIDNEY POWERS

# DISCUSSION

## MAGNETOMETER STUDY OF CADDO-SHREVEPORT UPLIFT, LOUISIANA

In the March *Bulletin* appeared a discussion by Douglas M. Collingwood of Wm. M. Barret's paper, "Magnetometer Study of Caddo-Shreveport Uplift, Louisiana." Mr. Barret's paper appeared in the February *Bulletin*, pages 175-83.

## INJUSTICE OF MISLEADING CITATIONS
## REPLY TO PROFESSOR R. T. CHAMBERLIN'S DISCUSSION

In the citation taken from his paper Professor Chamberlin makes it clear that he is aware of lateral thrusts having "caused a certain amount of mashing and compacting of the material of the beds," et cetera. He goes into sufficient detail to convince the most exacting critic that volume change, either increase or decrease, is a factor to be considered, and concludes the discussion with the following:

> Whether the importance of these various secondary factors is material and whether, if ignored, the balance of their sum-total tends toward an overestimate, or an underestimate, of the true extent of the crustal shortening, is here left to the individual judgment of each geologist guided by his own experience and insight.[1]

There is no denying that Professor Chamberlin is fully aware of *volume change*, but the extent, one way or the other, is left to "the individual judgment of the geologist." It is in place to inquire as to how Professor Chamberlin actually dealt with this factor. I quote the following.

> If one knows the average height to which the freshly folded tract was elevated, together with the amount of lateral shortening which has caused this elevation, it is a simple matter to calculate the thickness of the shell which suffered folding, *neglecting compression*, et cetera.[2] (The italics are mine.)

I am asking whether my statement, "Professor R. T. Chamberlin calculated the depth of the Appalachian folds on the basis of an unchanged or constant volume,"[3] was misleading? As double assurance that the statement was not, intentionally or otherwise, misleading, I quote from C. K. Leith, who, after devoting four pages to Professor Chamberlin's paper, points out several objections, including the following.

[1]R. T. Chamberlin, "Injustice of Misleading Citations," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 4 (April, 1930), pp. 521-22.

[2]R. T. Chamberlin, "The Appalachian Folds of Central Pennsylvania," *Jour. Geol.*, Vol. 18, No. 3 (April-May, 1910), p. 243.

[3]*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 2 (February, 1930), p. 241.

The calculations also assume that the volume of the rock mass affected has remained constant during deformation.[1]

I made no criticism against Professor Chamberlin, but merely called attention to the fact that he calculated the depth of Appalachian folds by means of a geometrical principle which, as is apparent to Professor Chamberlin or any one else, it would be extremely awkward to use if the factor of volume change were taken into consideration.

A few remarks may be added as to whether or not reference to Professor Chamberlin's paper was concerned with the discussion on the strain ellipsoid. Professor Mead objected to a footnote in my original article on the strain ellipsoid which reads as follows: "It is obvious that in considering a given sphere deformed into any imaginary ellipsoid, the two must be of equal volume."[1] He termed this as "contrary to fact," but added that, "Rigorously, it may be said that there can be no planes of no distortion except in the case involving no volume change."[2]

In my reply to Professor Mead's[3] objection I pointed out,

> inasmuch as the strain ellipsoid conception, as applied to structural geology, means very little or nothing without the planes of no distortion, anyone who uses it is doing so under the assumption of no volume change,

and then went on with the statement which involved a reference to Professor Chamberlin's paper of twenty years ago.

As the strain ellipsoid is a geometrical conception which involves the volume factor, and as the principle employed by Professor Chamberlin in determining the depth of folds is also a geometrical calculation involving volume (when considered in three dimensions), I regard reference to his paper as entirely appropriate.

THEODORE A. LINK

CALGARY, CANADA
March 10, 1930

[1]C. K. Leith, *Structural Geology* (Henry Holt and Company, New York, 1923), revised edition, pp. 196-99.

[1]Theodore A. Link, "Some Applications of the Strain Ellipsoid," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 11 (November, 1929), p. 1450.

[2]W. J. Mead, "Discussion," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 2 (February, 1930), p. 236.

[3]Theodore A. Link, "Author's Reply," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 2 (February, 1930), p. 241.

# RESEARCH NOTES

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The purpose of the Research Committee is the advancement of research within the field of petroleum geology. If members working actively in research on particular problems care to register with the Research Committee, the committee will be glad to aid them in any way it can and put them in touch with other men who are, or have been, working on similar or allied problems and can perhaps effect some integration of the research work of the Association. If the younger, or older, members of the Association, who are doing or preparing research for publication, will come to any member of the Committee, he will be very glad to offer whatever advice, counsel, or criticism he can in regard to the research, its prosecution, or its preparation for formal presentation. The Committee would be glad to have members formulate and present to it suggestions in regard to research problems and programs.

## CROOKED-HOLE REPORT

REPORT OF CHAIRMAN OF COMMITTEE ON STUDY OF CROOKED-HOLE PROBLEM

In the July number of our *Bulletin* for 1929, on page 853, preliminary announcement was made of a plan for studying the crooked-hole problem through the Research Committee of the American Association of Petroleum Geologists. A subcommittee was selected, known as the Committee on the Study of the Crooked-Hole Problem, and questionnaires[1] were sent out to all members of this Committee for distribution in their districts. The object of this study was to investigate and interpret the *geological* aspects of the problem, for, as pointed out in the first announcement, the *mechanical* aspects of the question were then being investigated by the American Petroleum Institute.

The personnel of this Committee was published on page 1227 of the September *Bulletin* for 1929, essentially as follows.

[1] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 7 (July, 1929), p. 854.

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|---|---|
| R. P. McLaughlin | Pacific Coast |
| W. E. Hubbard | Texas Panhandle |
| A. R. Denison | West Texas and Southeast New Mexico |
| W. C. Thompson | North Central Texas |
| C. H. Row | South Texas |
| F. C. Sealey and P. S. Justice | Gulf Coast |
| S. P. Borden | Arkansas and Northern Louisiana |
| S. H. Woods | Southern Oklahoma |
| D. R. Snow | Northern and Central Oklahoma |
| Marvin Lee | Kansas |
| J. French Robinson and J. G. Montgomery, Jr. | Eastern States |
| T. A. Link | Western Canada |
| O. B. Hopkins | Colombia and Peru |
| E. L. Estabrook | Venezuela |
| W. P. Haynes | Eastern Foreign Fields |
| F. H. Lahee | Chairman |

We wish to thank these gentlemen for their energy in this investigation and for their analyses of the conditions in their several districts.

The more significant facts brought out in the replies to the questionnaire are here listed.

1. Holes are more likely to deviate from the vertical when they are drilled through formations which consist of alternating soft and hard layers.

2. Deviation from the vertical is ordinarily gradual, seldom abrupt.

3. Much of the tendency to deviate may be overcome by proper drilling methods.

4. Cable-tool drilling, as well as rotary drilling, may produce crooked holes if drilling methods are careless, if the tools are inadequate, or if the formations penetrated have steep dips.

5. Relatively few attempts have been made to measure holes for direction, as well as angle of deviation from the vertical, so that almost no data were available to use in explaining the relations of a hole to the geological structure on which it is drilled, and to demonstrate the errors which may result in geological interpretation of subsurface conditions when holes are off the vertical.

From our canvass of the situation it became clear that the study of crooked holes is almost world-wide. The problem of drilling holes more nearly vertical has claimed the earnest attention of geologists, engineers, and operators not only in this country, but also in Canada, Mexico, Colombia, Peru, Venezuela, Argentina, Roumania, Persia, the East Indies, and other countries.

In America, in particular, through individual efforts and especially through the work of the American Petroleum Institute, tremendous advances were made during 1929 in seeking out the causes for crooked holes and in improving drilling machinery and drilling practice to correct the defective methods of the past. As a result of this improvement, our committee members from several districts advise that production men are no longer much concerned about crooked holes. Operators, contractors, and drillers have all shown a splendid willingness to coöperate for better drilling. It is stated that 200 wells completed in the late spring of 1929 in the Seminole district had 1/5 the average vertical correction of the same number prior to that time. None of these later

holes had a vertical correction of more than 25 feet at an average depth of 4,500 feet. The general consensus of opinion in many parts of the country seems to be that, as long as proper precaution is exercised in drilling, with frequent checking of the inclination of the hole by the acid-bottle method, the problem of drilling holes straight enough for "practical" purposes has been largely solved. This conclusion is reflected by John Franklin Dodge, in his excellent summary of the American Petroleum Institute's study of the problem, entitled "Straight Hole Drilling Practice,"[1] where he writes:

> It is realized that no hole is ever drilled exactly vertical to its completion. For the purpose of this discussion it is somewhat arbitrarily assumed that a reasonably straight hole is one in which the upper half (3,000 to 3,500 feet) does not deviate more than 2° or 3° from the vertical, and in the lower part the vertical angle does not exceed 8° or 10°.

I am calling attention to these sentiments mainly to emphasize the fact that a hole which is sufficiently straight from a mechanical point of view may not be sufficiently near the vertical from the geological standpoint. At a depth of several thousand feet, a well that is out of plumb as much as 5° or 10° may encounter the pay horizon several hundred feet from its intended point of penetration. This may not be significant on a broad low closed anticline, but it may be very important on salt-dome structures, fault structures, anticlines with steeply dipping flanks, and asymmetrical anticlines. And it certainly will be important on any structure where the spacing of wells in the pay formation is planned for scientific extraction of oil or gas.

For the present, with little accurate information at hand regarding the actual courses of holes underground, I do not think we can go much further in pointing out the geological discrepancies occasioned by drilling holes off the vertical.

F. H. LAHEE

DALLAS, TEXAS
March 24, 1930

[1]Delivered at the Chicago meeting of the American Petroleum Institute, December, 1929.

# REVIEWS AND NEW PUBLICATIONS

"The Saline Springs of Rio Salado" (Sandoval County, New Mexico). By JOHN D. CLARK, *University of New Mexico Bull. 163* (University, Albuquerque, August, 1929). 29 pp., 16 illus.

The brochure contains, in its 29 pages, 15 well-treated photographs, the logs of 2 wells, the account of 30 water samples, and a location sketch. References are made to papers by such pioneers as Matilda Coxe Stevenson, H. N. Herrick, George I. Adams, James H. Gardner, and to Kelly and Anspach —this last being a companion paper on Jemez Springs, published in September, 1913, now out of print. The bulletin on Rio Salado deserves wider notice because of several unusual features.

The occasion of Clark's contribution was the attempted plugging of a well drilled for gas and oil, but which finally yielded from all sands a combined flow of "5.5 cubic feet per second," or about 86,000 barrels per day of somewhat saline, highly carbonated water, scalding hot (123° F.). Because of the heavy expense of attempted plugging, as well as several ingeniously suggested economic benefits (health resort, live-stock water, control of evaporation and deposition from neighboring springs, irrigation, and manufacturing), the well was allowed to flow wide open. The effect of this applied physical chemistry and economics has also been to compromise the common resultant legal situation where plugging is hardly possible.

This well was located as high as feasible structurally,—being on a distinct anticline (nose), which had been discovered about 1925 by a reputable Rocky Mountain petroleum geologist who had evidently trusted too much in a fault closure along its eastern side, against the Nacimiento Mountain uplift. Along this fault saline, carbonated springs—now rather cool—have built craters and other heavy surface deposits of travertine. After a contract had been made to drill a well into a certain Pennsylvanian formation, the reviewer was called in (August, 1925) to detail for a location on this structure better than one where a heavy flow (25,000 barrels per day) of similar highly mineralized water had been tapped (April, 1925—not 1926, as dated in bulletin) at a shallow depth (445 feet). He mapped a huge nose on the Todilto (Jurassic) gypsum, which is here a fair datum, and located a second well in the SE. ¼ of Sec. 1, T. 16 N., R. 1 W., approximately 200 feet higher structurally than No. 1, and about 2 miles north of it. The log published in Clark's bulletin shows that this second well was drilled to 2,008 feet, and that it, too, had several flows of highly saline and carbonated water from several sands, as hot as 108° F. at 425 feet and 142° F. at 1,920 feet, casinghead temperature of the entire flow being 123° F. Casinghead pressure was 25 pounds per square inch. The water is at first snow-white, then sparkling, with escaping carbon dioxide.

The preceding account is of interest in connection with the remarks of John L. Rich[1] in discussing the probable gravitational flushing of oil out of the

[1] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 7, No. 3 (May-June, 1923), pp. 216-17.

rocks on the eastern side of San Juan Basin as a reason for lack of production there, as contrasted with production on the western side where oil-bearing strata are penetrated at considerably lower elevations than barren strata of the same age on the eastern side. It seems probable that a soda-water drive on the eastern side, such as here indicated, may at least locally have caused oil migration out of the structures of that region.

CHARLES T. KIRK

TULSA, OKLAHOMA
April 1, 1930

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"Insoluble Residues as a Guide in Stratigraphic Studies." By H. S. MCQUEEN. *Missouri Bureau of Geology and Mines*, Appendix 1, Preprint from 56th Biennial Report, 1931 (December, 1929). 30 pp. 12 plates.

Many of the Cambrian and Lower Ordovician (Cambrian, Ozarkian, and Canadian of Ulrich) formations of the Ozark region are distinguished on the outcrop by peculiar varieties of chert. Following the suggestion of Ulrich that these distinctive cherts are the result of concentration by weathering of the siliceous content of dolomites and limestones, the Lower Ordovician and Cambrian dolomites and limestones were investigated to learn if the insoluble residues of these formations might not be equally distinctive. The study has established the fact that formations can be distinguished by their insoluble residues. Thus a new and important method of correlation is added to those methods already used by the microscopist.

The limestone or dolomite is completely digested in dilute hydrochloric acid, and the residue thoroughly washed and dried. The residue is examined under a wide-field binocular microscope.

The insoluble residues of the Cambrian, Ozarkian, and Canadian formations of Missouri are described in detail and beautifully illustrated. Chert is the predominant insoluble material. It varies in character, and these variations are of such a nature and so restricted in occurrence that they indicate formational units. The Eminence, Van Buren, Gasconade, and Cotter formations are characterized by plentiful and distinctive chert. Some formations, such as the Proctor and Cambrian formations, are distinguished by an almost complete absence of chert. Sand comes next to chert in amount, and also varies in character. The Upper Cambrian sands differ from the Lower Ordovician sands. A peculiar cherty sand is characteristic of the Roubidoux formation. Shale predominates in the insoluble residues of the Bonneterre and Davis formations, and is sufficiently distinct in character to be diagnostic. Clay, silt, and heavy minerals are present in the residues but were not studied in detail. Plentiful glauconite is characteristic of the Bonneterre.

A peculiar feature of the insoluble residues studied is the presence of casts of dolomite crystals called dolocasts in the chert, shale, glauconite, pyrite, or limonite of the insoluble residues from dolomites. The dolocasts vary in character enough to assist in the identification of certain horizons. Siliceous oölites are present in some formations in profusion, and certain significant differences were noticed that serve to tell formations apart.

Although only the aforementioned formations of Missouri were studied in detail, enough work was done on other formations to demonstrate that the Kimmswick, Fernvale, Maquoketa, Mississippian, Kansas City, Lansing, and Douglas formations carry distinctive residues. Also, the "Siliceous lime" of Kansas and Oklahoma can be divided into zones which persist over wide areas.

Three cross sections accompany the report. They show convincingly the reasonableness of the correlations based on insoluble residues. A north-south section through western Missouri shows a complete absence of the Davis, Derby-Doerun, and Potosi formations, and the presence of a pre-Cambrian ridge at Rinehart. A north-south section through central Missouri shows the presence of the Potosi and Davis formations, the thickening of formations below the base of the Gasconade dolomite, and suggests that the crest of the regional structure is in the vicinity of Decaturville. An east-west section through southern Missouri shows the local absence of certain formations, and the thickening of the section toward the east.

The reviewer wishes to stress the importance of this contribution. The microscopist working with Paleozoic formations is frequently confronted with unfossiliferous formations, sparingly fossiliferous formations, and fossiliferous formations that do not contain diagnostic faunas. He is often in need of a check for his identifications based on lithology and paleontology. The increasing importance of the Lower Ordovician (Canadian) as a producer of oil demands more detailed correlations, which can best be made by a study of insoluble residues. The accuracy of correlation by this method, and the speed with which the work can be carried on, will undoubtedly encourage a wide adoption of the method, and further research work on younger formations. A panacea for the difficulties of correlation has not been discovered, but a valuable refined lithologic method has been added to those methods of correlation already in use.

IRA H. CRAM

TULSA, OKLAHOMA
April 6, 1930

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## RECENT PUBLICATIONS

### CALIFORNIA

"Geology of Southwestern Kern County, California," by H. W. Hoots. *U. S. Geol. Survey Bull. 812-D* (Supt. Documents, Washington, D. C., 1930). Price, $0.50.

### COLORADO

"Geology and Coal Resources of the Meeker Quadrangle, Moffat and Rio Blanco Counties, Colorado," by E. T. Hancock and J. B. Eby. *U. S. Geol. Survey Bull. 812-C* (Supt. Documents, Washington, D. C., 1930), pp. 191-242, Pls. 19-30, Figs. 5-6. Price, $0.30.

"The Granby Anticline, Grand County, Colorado," by T. S. Lovering. *U. S. Geol. Survey Bull. 822-B* (Supt. Documents, Washington, D. C., 1930), pp. 71-76, Pl. 6. Price $0.05.

FRANCE

"Die Erdölsuche in Pyrenäenvorlande," by Pierre Viennot. *Petrol. Zeits.*, Vol. 26, No. 14 (April 2, 1930), pp. 422-28, illus.

GENERAL

"Cyclical Sedimentation of the Pennsylvanian Period and its Significance," by J. Marvin Weller. *Jour. Geol.*, Vol. 38, No. 2 (Chicago, February-March, 1930), pp. 97-135, 6 figs.

"Petroleum Geology," by V. C. Illing. *Inst. Petrol. Tech.*, Vol. 16, No. 80 (London, March, 1930), pp. 91-96.

"Oilfield Practice," by A. Beeby Thompson. *Inst. Petrol. Tech.*, Vol. 16, No. 80 (March, 1930), pp. 108-17.

"Natural Gas," by S. C. Carney. *Inst. Petrol. Tech.*, Vol. 16, No. 80 (March, 1930), pp. 118-24.

*American Petroleum Refining*, by H. S. Bell. D. Van Nostrand Company, Inc. (New York, 1930). A new completely revised edition of this comprehensive work. Recent developments and standard methods in oil refining are covered in detail from crude at the tank farm to refined products in tank car and steamer. Buckram, 630 pp., 6 × 9¼ inches, illus. Price, $6.00.

*Petroleum Vademecum*, 7th ed. (1930). Compiled by Robert Schwarz. International petroleum tables. Chemical-physical measures, weights, units; oil tariffs; statistics. Contains an orientative colored map of the world's oil industry. Published by Verlag für Fachliteratur (Berlin, W. 62, Courbièrestr. 3). 2 vols., 604 pp; illus.; map in pocket. Price, 24 M. ($6.00).

GEOPHYSICS

"Review of the Geophysical Methods of Prospecting," by Donald C. Barton and E. Buhler Summers. *Geographical Review* (New York, April, 1930), pp. 288-300.

"Geophysics," by W. H. Fordham. *Inst. Petrol. Tech.*, Vol. 16, No. 80 (March, 1930), pp. 97-107.

MADAGASCAR

"Les recherches pétrolifères dans l'ouest de Madegascar," by H. Besairie. *La Revue Pétrolifère* (Paris, March 22, 1930), pp. 409-11, illus.

MEXICO

"Geological Cross Section of Isthmus of Tehuantepec," by Charles Laurence Baker. *Pan-Amer. Geol.*, Vol. 53, No. 3 (Des Moines, Iowa, April, 1930), pp. 161-74, 1 fig.

"Oil Possibilities of the Colorado River Delta Region," by T. F. Stipp. *Oil Bulletin* (Los Angeles, April, 1930), pp. 375-77, 450; illus.

OKLAHOMA

"Oil and Gas in Oklahoma. Love and Marshall Counties," by Fred M. Bullard and John S. Redfield. *Oklahoma Geol. Survey Bull. 40-OO* (Norman, March, 1930). 30 pp., 1 pl., 5 figs.

PENNSYLVANIA AND NEW YORK

"Recent Developments in Flooding Practice in the Bradford and Richburg Oil Fields," by Charles R. Fettke. *Amer. Inst. Min. Met. Eng. Tech. Pub. 328* (New York, 1930). 30 pp., 11 figs.

ROUMANIA

"Über rumänische Salztonaufbrüche," by A. Pustowka. *Intern. Zeits. für Bohrtechnik, Erdölbergbau und Geologie* (Vienna, March 15, 1930), pp. 56-60, illus.

# THE ASSOCIATION ROUND TABLE

## MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

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V. E. Monnett, C. E. Decker, A. J. Williams
James Lawrence Muir, Enid, Okla.
C. E. Decker, V. E. Monnett, G. E. Anderson
Arthur Armstrong Nichols, Tulsa, Okla.
N. W. Bass, R. M. Beatty, E. S. Roark
Paul Ferris Osborne, Denver, Colo.
E. Russell Lloyd, Prentice F. Brown, Georges Vorbe
Luther Edwin Patterson, Jr., Norman, Okla.
C. E. Decker, V. E. Monnett, A. J. Williams
Ben Luther Pilcher, Jr., Dallas, Tex.
E. H. Sellards, W. S. Adkins, F. B. Plummer
Darrell Milton Putman, Tulsa, Okla.
Hubert S. Bale, Elfred Beck, E. F. Miller
Edward Wilson Rumsey, Tulsa, Okla.
Elfred Beck, W. W. Rusk, Robert Wesley Brown
Richard Walker Simpson, Jr., Houston, Tex.
B. E. Thompson, Parker A. Robertson, H. B. Fuqua
Milton Heyer Sperling, Los Angeles, Calif.
F. E. Vaughan, T. F. Stipp, J. P. Buwalda
Zenas E. Stuckey, Norman, Okla.
C. E. Decker, V. E. Monnett, A. J. Williams
Leonard Colburn Thomas, Maracaibo, Venezuela
C. A. Baird, C. L. Griffith, P. C. Nolan
Abe Travis, Tulsa, Okla.
V. E. Monnett, C. E. Decker, G. E. Anderson

Michael Willmer Forbes Tweedie, Maracaibo, Venezuela
H. E. Van Aubel, C. A. Baird, P. C. Nolan
Fritz E. von Estorff, San Francisco, Calif.
G. C. Gester, S. H. Gester, G. M. Cunningham
Rudolf von Zwerger, Shreveport, La.
C. L. Moody, R. G. Copeland, M. W. Grimm
William Edmund Wallis, Golden, Colo.
W. A. Waldschmidt, J. Harlan Johnson, F. M. Van Tuyl
William Orville Wethington, Norman, Okla.
V. E. Monnett, A. J. Williams, C. E. Decker
Thomas Carroll Wilson, Maracaibo, Venezuela
C. A. Baird, C. L. Griffith, P. C. Nolan
George Robert Wood, Tulsa, Okla.
A. W. Lauer, Harry F. Wright, Max A. Pishel
Ray A. Hancock, Fullerton, Calif.
N. L. Taliaferro, L. C. Uren, Carlton D. Hulin

FOR TRANSFER TO ACTIVE MEMBERSHIP

Dwight Hemenway Bingham, Houston, Tex.
H. E. Minor, Marcus A. Hanna, C. N. Housh
Arnold Sylvester Bunte, St. Louis, Mo.
E. L. Jones, W. H. Whittier, W. C. Bean
William Paul Jenny, New York, N. Y.
Paul Weaver, J. Brian Eby, John G. Weinzierl
Edward Lee Johnson, San Antonio, Tex.
A. W. Weeks, F. W. Bartlett, K. H. Schilling
Walter Kauenhowen, Shreveport, La.
C. L. Moody, R. G. Copeland, M. W. Grimm
Clark Russell Steinberger, Findlay, Ohio
E. R. Brockway, V. E. Monnett, Charles E. Decker
Everett Harold Tollefson, Pittsburgh, Pa.
W. Dow Hamm, F. W. Bartlett, E. G. Allen

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## FIFTEENTH ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS ROOSEVELT HOTEL, NEW ORLEANS, LOUISIANA MARCH 20-22, 1930

### COMMITTEES

*General Arrangements.*—J. Y. Snyder, president; R. S. McFarland, past-president; Fred H. Kay, first vice-president; A. R. Denison, second vice-president; F. H. Lahee, third vice-president

*Shreveport Committee.*—M. W. Grimm, chairman; S. P. Borden, W. F. Chisholm, C. M. Dorchester, W. E. Hopper

*Technical Program.*—F. H. Lahee, general chairman. *Gulf Coast Papers.*—W. C. Spooner, chairman; A. F. Crider, Phillip S. Justice, Donald J. Munroe, W. Armstrong Price, R. A. Steinmayer. *Foreign Papers.*—G. C. Gester, W. B. Heroy

*Geophysical Papers.*—D. C. Barton, chairman

*Reception.*—R. A. Steinmayer, chairman; A. F. Crider, Roy Hazzard, H. V. Howe, W. C. Spooner

*Ladies.*—Mrs. S. P. Borden, general chairman; Mrs. R. A. Steinmayer, local chairman; Mrs. A. F. Crider, Mrs. H. V. Howe, Mrs. J. Y. Snyder, Mrs. G. R. Stevens

*"Stunt Night on the Mighty Mississippi."*—George R. Stevens, chairman; L. A. Barton, E. H. Finch, L. S. Harlowe, Paul Madden

*Golf.*—L. A. Barton, chairman; H. C. Ferrell, local chairman; A. F. Crider, F. X. Bostick, F. J. Miller, Louis C. Roberts, Jr., H. G. Schneider, R. A. Steinmayer

*Special Side Trips.*—R. A. Steinmayer, chairman; John L. Henning

*Evangeline-Country Trip.*—G. W. Schneider, chairman; C. C. Clark, A. F. Crider, S. C. Stathers, J. O. Nelson

*Entertainment.*—Howard S. Greene, director

*Hotels.*—Seymour Weiss, assistant manager, Roosevelt Hotel

### Society of Economic Paleontologists and Mineralogists

The Society of Economic Paleontologists and Mineralogists elected the following officers: Joseph A. Cushman, president; C. C. Church, vice-president; Gayle Scott, secretary-treasurer; and Raymond C. Moore, editor.

### Golf Tournament

The annual golf tournament was held at the Audubon Club. The number of players was twenty-eight. Low scores are here given.

Low gross score, winning J. Y. Snyder prize—D. E. Mathes, Dallas, Texas (score, 82; handicap, 18; net, 64)

Low net score, winning inscription on shield of J. Wallace Bostick trophy—D. E. Mathes, Dallas, Texas (score, 82; handicap, 18; net, 64)

As there was no competition among non-members for the J. Wallace Bostick cup, the cup was not awarded this year.

### Schedule of Events

#### PRE-CONVENTION

#### TUESDAY, MARCH 18

10:00 A. M. Constitution committee—Max W. Ball, chairman (Mezzanine)
2:00 P. M. Executive committee—J. Y. Snyder, president

#### WEDNESDAY, MARCH 19

8:00 A. M. Special trip from Lafayette, Louisiana, to Evangeline country and salt domes
10:00 A. M. Registration and exhibit booths open (Venetian Room, Lobby Floor)
10:00 A. M. Research committee—Alex W. McCoy, chairman (Mezzanine)
2:00 P. M. General business committee—Wallace E. Pratt, chairman (Mezzanine)

#### CONVENTION

#### THURSDAY, MARCH 20

8:00 A. M. Registration
A. M. Ladies' geological group, election of officers (inquire at ladies' registration desk, Venetian Room)
10:00 A. M. Introduction—R. A. Steinmayer, chairman, reception committee (Tip-Top Inn, 12th Floor)
Address of welcome—A. B. Dinwiddie, president of Tulane University
Response—R. S. McFarland

10:30 A. M. Technical session (Tip-Top Inn, 12th Floor)
2:00 P. M. Technical session (Tip-Top Inn, 12th Floor)
2:00 P. M. Ladies' trip through Vieux Carre
4:45 P. M. Nomination of officers
Appointment of committees
8:00 P. M. "Stunt Night on the Mighty Mississippi." Entertainment and dancing. (Busses leave entrance Roosevelt Hotel, 7:30 P. M.)

FRIDAY, MARCH 21

8:00 A. M. Ballot boxes open (A. A. P. G. booth, Venetian Room, Lobby Floor)
9:00 A. M. Technical session (Tip-Top Inn, 12th Floor)
9:00 A. M. Society of Economic Paleontologists and Mineralogists, technical session (Mezzanine, Gold Room)
9:00 A. M. Society of Economic Geophysicists, technical session (Mezzanine, Room E)
12:45 P. M. Ladies' luncheon (French Quarter restaurants)
1:00 P. M. A. A. P. G. golf tournament (Audubon Club)
2:00 P. M. Ladies' theater party
2:00 P. M. Technical session (Tip-Top Inn, 12th Floor)
2:00 P. M. Society of Economic Paleontologists and Mineralogists, business meeting (2:00-3:00); technical session (3:00-5:00) (Mezzanine, Gold Room)
2:00 P. M. Society of Economic Geophysicists, technical session (Mezzanine, Room E)
3:30 P. M. Foreign papers (Mezzanine, Room E)
8:00 P. M. Public illustrated lecture—Arthur L. Day of the Carnegie Institution, Washington, D. C., "Some Features of Active Volcanoes" (Crescent Theater, adjoining Roosevelt Hotel)
9:30 P. M. Buffet dance (evening dress not required), (Tip-Top Inn, 12th Floor)

SATURDAY, MARCH 22

9:00 A. M. 15th annual business meeting (Tip-Top Inn)
Announcement of annual elections
10:00 A. M. Technical session (Tip-Top Inn)
12:45 P. M. Ladies' geological group luncheon (La Louisiane)
2:00 P. M. Technical session (Tip-Top Inn)

## PAPERS

### GROUP I. MISSISSIPPI EMBAYMENT

1. Tertiary History of the Region of the Sabine Uplift, Louisiana—C. L. MOODY
2. Phases of Sedimentation in the Gulf Coastal Plain of Louisiana—R. A. STEINMAYER
3. Contribution to the Cenozoic History of the Texas Plains—CHARLES LAURENCE BAKER
4. Marine Oligocene of the Coastal Plain of Texas and Louisiana—ALVA C. ELLISOR
5. Post-Oligocene Subsurface Problem of Texas—MARCUS A. HANNA
6. Sedimentation in the Eastern Part of the Mississippi Embayment in Eocene Time—RALPH E. GRIM
7. Oligocene and Miocene Formations of Southwestern Alabama—D. R. SEMMES
8. Comanche Series of Louisiana and Arkansas—W. C. SPOONER and R. T. HAZZARD
9. Deep Sand Developments in Cotton Valley Field, Webster Parish, Louisiana—J. S. ROSS
10. Geological and Geophysical Notes on Van Structure, Van Zandt County, Texas—R. A. LIDDLE

11. Clay Creek Field, Washington County, Texas—F. E. HEATH, J. A. WATERS, and J. B. FERGUSON
12. Salt Flat Field, Caldwell County, Texas—L. F. MCCOLLUM, S. O. BURFORD, and C. J. CUNNINGHAM
13. Pre-Cretaceous Rocks in Wells of the Gulf Coastal Plain South of the Ouachita Mountains—H. D. MISER
14. Evidence from Wells Penetrating the Coastal Plain in Alabama and Georgia on the Nature and Inclination of the Crystalline Basement—D. R. SEMMES
15. Pre-Cretaceous Rocks of the Balcones Fault Zone of Texas—E. H. SELLARDS
16. Pre-Cretaceous Rocks of Arkansas—W. C. SPOONER
17. Probable Age of the Balcones Fault, Texas—ROBERT H. CUYLER
18. The Building of the Mississippi Delta—A. C. TROWBRIDGE
19. Surface Geology of Coastal Southeast Texas—DONALD C. BARTON
20. Physiography of the Corpus Christi Area, Texas—W. ARMSTRONG PRICE
21. Deep Sand Development at Barbers Hill Salt Dome—P. C. MURPHY and SIDNEY A. JUDSON
22. Review of Petroleum Potentialities of the Texas-Louisiana Gulf Coast—DONALD C. BARTON
23. The Refugio Field, Refugio County, Texas—A. G. MADDREN and JOHN S. CRUSE, Jr.
24. The White Point and Saxet Fields, San Patricio and Nueces Counties, Texas—W. ARMSTRONG PRICE
25. Geology of Catahoula Parish, Louisiana—H. K. SHEARER
26. Dixie Oil Pool, Caddo Parish, Louisiana—H. K. SHEARER and E. B. HUTSON
27. Faulting in Southwestern Arkansas—C. L. RANKIN
28. Some Difficulties in the Development of Southern Louisiana Salt Domes—E. R. AMES
29. Cretaceous and Tertiary Sediments of Kentucky, Illinois, and Missouri—J. E. LAMAR and A. H. SUTTON
30 Surface and Subsurface Structure of the Tri-County Oil Field of Southwestern Indiana—J. M. WANENMACHER

GROUP II GENERAL TECHNICAL SUBJECTS

1. Geothermal Variations in Some Oil Fields of the Los Angeles Basin, California—ANDERS J. CARLSON
2. Determination of Geothermal Gradients in Oklahoma—JOHN A. MCCUTCHIN
3. Geothermal Gradients in Texas—E. M. HAWTOF
4. Data on Sulphate-Reducing Bacteria in Soils and Waters of Illinois Coal Fields—EDSON S. BASTIN and FRANK E. GREER
5. Origin and Environment of Source Sediments: Summary Report of Progress—PARKER D. TRASK
6. Geophysical Prospecting for Oil—DONALD C. BARTON
7. Factors Influencing the Selection of the Geophysical Method in Accordance with the Subsurface Problem to Be Solved—FRANK RIEBER
8. Crooked-Hole Problems in the Gulf Coast—P. C. MURPHY and SIDNEY A. JUDSON
9. Accuracy of Bore-Hole Surveying by Orientation From the Surface—R. P. MCLAUGHLIN
10. Crooked Holes in Turner Valley, Alberta, Canada—E. P. VAN DER LINDEN
11. Effects of Metamorphism on Certain Débris in Source Sediments—TAISIA STADNICHENKO
12. Orientation of Cores—GEORGE A. MACREADY
13. Use of Airplane Photographs in Geologic Mapping—WALTER A. ENGLISH
14. Geochemical Studies of the Woodbine Sand in East Texas—F. B. PLUMMER and E. C. SARGENT
15. Practical Determination of the Optimum Spacing of Oil Wells—ROSWELL H. JOHNSON and SYLVESTER H. RYNEARSON

16. Relative Reliability in Structure-Contour Maps Made From Comparative Elevations and From Dip Readings—ROSWELL H. JOHNSON and FRANK G. HARRIS
17. Experiments Relating to Salt-Dome Structures—THEODORE A. LINK
18. Contribution to the Salt Dome Problem—F. M. VAN TUYL
19. Use of Vegetation as an Indicator of Geologic Formations—ROBERT F. CUYLER
20. Temperature Gradients in Permian Basin of West Texas and Eastern New Mexico—W. B. LANG
21. An Interesting Case of Deflecting Diamond Drill Holes—ROBERT DAVIS LONGYEAR

GROUP III. AREA OUTSIDE OF MISSISSIPPI EMBAYMENT

1. Pennsylvanian Overlap in the United States—A. I. LEVORSEN
2. Oklahoma City Oil Field, Oklahoma—R. J. RIGGS and HOMER H. CHARLES
3. Subdivision of the Simpson of the Arbuckle and Wichita Mountains of Oklahoma and Correlation of the Formations—CHARLES E. DECKER
4. The Simpson of Central Oklahoma—T. E. WEIRICH
5. Permian Formations of Northwestern Oklahoma and Adjacent Areas—R. L. CLIFTON
6. Pre-Dakota Stratigraphy of the Rocky Mountain Front Range of Colorado and Wyoming—S. H. KNIGHT
7. Stratigraphy of the Turner Valley Field, Canada—P. D. MOORE
8. The Alberta Syncline, Canada—THEODORE A. LINK
9. The Ancestral Rockies—WALTER A. VER WIEBE
10. Subsurface Distribution of Pre-Mississippian Rocks of Kansas and Oklahoma—HUGH MCCLELLAN
11. An Unconformity in the Colorado Group in Eastern Colorado—J. HARLAN JOHNSON
12. Some Further Suggestions About Permo-Carboniferous Orogeny in South-Central United States—W. A. J. M. VAN DER GRACHT
13. Origin of the Oil and Its Reservoir in the Yates Pool, Pecos County, Texas—JOHN EMERY ADAMS
14. The Hendrick Pool, Winkler County, Texas—A. L. ACKERS, R. DECHICCHIS and R. H. SMITH
15. Geology of Vermilion Creek Gas Area in Southwest Wyoming and Northwest Colorado—W. T. NIGHTINGALE
16. Preliminary Report on the Geology of Montague County, Texas—FRED M. BULLARD and ROBERT H. CUYLER
17. Valley Center Oil Field, Sedgwick County, Kansas—ROY H. HALL and ARTHUR PRICE
18. Igneous Rock in the Deep Shell Well in Pecos County, Texas—E. L. JONES, Jr., and RUSSELL C. CONKLING
19. Geological and Geophysical Notes on the Hobbs Oil Field, Lea County, New Mexico—R. CLARE COFFIN and R. K. DEFORD
20. Guadalupian Stratigraphy—A Discussion—E. RUSSELL LLOYD
21. Progress of A. A. P. G. Coöperative Mapping Project in Texas—F. B. PLUMMER

GEOPHYSICS GROUP

1. Review of Geophysical Prospecting for Petroleum—DONALD C. BARTON
2. Magnetometer Study of the Caddo-Shreveport Uplift, Louisiana—WILLIAM M. BARRET
3. Magnetometer Survey of Little Fry Pan Area, Uvalde and Kinney Counties, Texas—R. A. LIDDLE
4. Magnetics and Geology of the Yost Field, Bastrop County, Texas—D. M. COLLINGWOOD
5. Relations Between Magnetic Susceptibility and Content of Magnetite in Sands and Shales—D. M. COLLINGWOOD

6. Wave-Front Diagrams in Seismic Interpretation—R. L. THORNBURGH
7. Transmission of the Instant of Explosion in Seismic Prospecting—C. A. HEILAND
8. Notes on Geophysical Investigations in Colorado—C. A. HEILAND and JOHN H. WILSON
9. Some Results of Elastic-Wave Surveys in California and Elsewhere—FRANK RIEBER
10. Electrical Prospecting for Oil Structure—KARL SUNDBERG
11. An Electrical Survey of Structural Conditions in the Salt Flat Field, Caldwell County, Texas—HELMER HEDSTROM
12. Geo-Electric Investigations on Non-Conductors—Some Examples—NORBERT GELLA
13. Torsion-Balance Survey of the Esperson Dome, Liberty County, Texas—DONALD C. BARTON
14. Teaching of Geophysical Prospecting—C. A. HEILAND
15. Comparative Study of Geologic and Gradient Maps, Blue Ridge Salt Dome, Fort Bend County, Texas—JOHN F. WEINZIERL

FOREIGN PAPERS

1. Geology of Prospective Oil Territory in the Republic of Turkey—SHIRLEY L. MASON
2. Oil Possibilities of France—FREDERICK G. CLAPP
3. A Reconnaissance in Northern Persia—FREDERICK G. CLAPP
4. Geology of Russian Oil Fields—BASIL B. ZAVOICO
5. Geology of Southwest Ecuador—GEORGE SHEPPARD

PALEONTOLOGY

1. Relative Abundance of Species of *Foraminifera* at Type Localities of Byram Marl and Red Bluff Clay—HENRY V. HOWE
2. Fossil Zonation in Fredericksburg and Washita Divisions of Texas Comanche—W. S. ADKINS
3. Tertiary Climates and Correlation—RALPH W. CHANEY
4. Corals of Trinity Division of Cretaceous of Central Texas—JOHN W. WELLS and F. L. WHITNEY
5. Some Upper Carboniferous *Foraminifera* from the Shale Basin of Western Texas—DAVID M. DELO
6. *Tetraloculina*: A New Genus of *Foraminifera* from Santa Barbara, California—JOHN DANIEL GILBOE
7. Pennsylvanian Climates and Paleontology—ALBERT W. GILES
8 An American Record of Genus *Orbitoides*, *Orbitoides Palmeri* N. Sp. from Cuba—D. W. GRAVELL
9. Zonation of Permian and Pennsylvanian Systems of North Central Texas by Means of Fossil Cephalopods—F. B. PLUMMER and GAYLE SCOTT
10. Review of the Genus *Rouxia*—G. DALLAS HANNA
11. Ostracod Fauna of Bromide or Upper Simpson Formation of Oklahoma—R. W. HARRIS
12. Range of Niobrara and Benton Fossils in Colorado and Adjacent Areas—J. HARLAN JOHNSON
13. Geologically Ancient Man in America—HAROLD J. COOK
14. Distinctive New Species of *Foraminifera* from Oligocene of Mississippi—HENRY V. HOWE
15. Recent Littoral *Foraminifera* of Texas and Louisiana—MOSES M. KORNFELD
16. The Cephalopod Fauna of Admiral Formation of Wichita Group of North-Central Texas—F. B. PLUMMER and GAYLE SCOTT
17. Some Pelecypods of Glen Rose Formation—MINETTE LILLIAN RIES and F. L. WHITNEY
18. Arenaceous *Foraminifera* from Ordovician and Silurian Limestones of Oklahoma—W. L. MOREMAN

19. Regional Extent of Marmaton and Cherokee—ROBERT ROTH
20. New Pelecypods from Glen Rose Formation of Central Texas—F. L. WHITNEY
21. A Burrow? From Mount Selman Formation—F. L. WHITNEY
22. The Genus *Bolivininella* in the Oligocene of Mississippi—HENRY V. HOWE
23. Cephalopod Fauna of Caddo Creek Formation of Canyon Group—GAYLE SCOTT and F. B. PLUMMER
24. Fauna of Travis Peak Formation of Central Texas—F. L. WHITNEY and ROBERT H. CUYLER
25. Some Calcareous Algae from Comanche of Texas—F. L. WHITNEY and MARION I. WHITNEY
26. Petrographic Characteristics of Oklahoma Red-Beds—MARIA SPENCER

Total registration at the meeting was 980: 1 honorary member; 448 active members; 89 associate members; 150 non-member men; and 292 non-member women.

MEMBERS REGISTERED AT FIFTEENTH ANNUAL MEETING

HONORARY (*), ACTIVE (unmarked), ASSOCIATE (||)

Ackers, A. L., Midland, Texas
Adams, Frank C., Houston, Tex.
Adams, George I., Tuscaloosa, Ala.
Adams, John Emery, Midland, Tex.
Adams, W. C., Tulsa, Okla.
Adkins, W. S., Austin, Tex.
Aid, Herbert, Wichita Falls, Tex.
Ainsworth, William L., Wichita, Kan.
Ames, E. R., Orange, Tex.
Ames, Edward W., San Antonio, Tex.
Anderson, Carl B., Tulsa, Okla.
Anderson, Lyman P., San Angelo, Tex.
Andreen, Harry M., Tulsa, Okla.
Applin, Paul L., Fort Worth, Tex.
Armstrong, J. M., Eastland, Tex.
Athy, Lawrence F., Ponca City, Okla.
Atkinson, William H., Oklahoma City, Okla.
Aurand, Harry A., Denver, Colo.
Aurin, Fritz L., Ponca City, Okla.
Avery, C. Dwight, Washington, D. C.

Bace, A. C., San Angelo, Tex.
Baker, Charles L., Houston, Tex.
Baldwin, E. B., Victoria, Tex.
Bale, Hubert E., Oklahoma City, Okla.
||Ballard, James L., Tyler, Tex.
Banks, Thomas R., Corpus Christi, Tex.
Barnes, Roy M., Los Angeles, Calif.
Barrow, Leonidas T., Houston, Tex.
||Bartell, Laurence D., Oklahoma City, Okla.
||Bartlett, C. Lothrop, Dallas, Tex.
Barton, Donald C., Houston, Tex.
Barton, Louis A., Shreveport, La.
Bayer, H. M., Midland, Tex.
Beck, Elfred, Tulsa, Okla.
Beckelhymer, Roy L., Dallas, Tex.
Becker, Clyde M., Chickasha, Okla.
Behre, Charles H., Jr., Cincinnati, Ohio
||Beilharz, Carl F., El Dorado, Ark.
Belt, Ben C., Houston, Tex.
Benedum, Darwin, San Antonio, Tex.
Berger, Walter R., Fort Worth, Tex.
Bernard, W. E., Tulsa, Okla.
Best, J. Boyd, Houston, Tex.
Bierman, Alfred C., Wichita Falls, Tex.
Birk, Ralph A., Wichita Falls, Tex.
||Blackburn, Willis C., Corpus Christi, Tex.
||Blanchard, J. B., San Antonio, Tex.
Blanchard, W. Grant, Jr., Dallas, Tex.
Blanpied, B. W., Meridian, Miss.
Borden, S. P., Shreveport, La.
Bostick, J. Wallace, Dallas, Tex.
Bowen, James P., Wichita Falls, Tex.
||Bowling, Leslie, Houston, Tex.
Bowman, Wayne F., Houston, Tex.
Boyer, Will W., Casper, Wyo.
Boyle, Albert C., Jr., Laramie, Wyo.
Boyle, Walter J., Fort Worth, Tex.
Brainerd, Arthur E., Ponca City, Okla.
Brainerd, William F., Wichita Falls, Tex.
Branner, George C., Little Rock, Ark.
Branson, E. B., Columbia, Mo.
Brehm, Ralph C., Tulsa, Okla.
||Brice, John W., Brenham, Tex.
Brown, J. Earle, Fort Worth, Tex.
Browning, Iley B., Ashland, Ky.
Bruyere, Alan, Fort Worth, Tex.
||Bryant, Howard S., Wichita, Kan.
||Buchner, Carl F., St. Louis, Mo.
Bullard, Edgar F., Tulsa, Okla.
Bullard, Fred M., Austin, Tex.
Bunn, John R., Ardmore, Okla.
Burt, Roy A., Kansas City, Mo.
Butcher, Seldon D., Tulsa, Okla.
Butterworth, E. M., Los Angeles, Calif.

Byrd, David Harold, Dallas, Tex.

Cannon, Joe, San Angelo, Tex.
Cannon, R. L., San Angelo, Tex.
Carlton, Dave P., Houston, Tex.
Carsey, J. Ben, McCamey, Tex.
||Carter, DeVere V., Houston, Tex.
Cartwright, Lon D., Jr., San Angelo, Tex.
||Chatman, Cecil L., McCamey, Tex.
Cheney, M. G., Coleman, Tex.
Chisholm, William F., Shreveport, La.
Christie, Laurence G., Houston, Tex.
Christner, D. D., Fort Worth, Tex.
||Christner, J. B., Lockhart, Tex.
Clark, Chester C., Shreveport, La.
Clark, Glenn C., Ponca City, Okla.
Clark, H. Smith, Fort Worth, Tex.
||Clark, L. W., San Antonio, Tex.
Clark, Robert W., Pittsburgh, Pa.
Clark, Stuart K., Ponca City, Okla.
Clopton, John Hale, San Antonio, Tex.
Cloyes, S. B., Tulsa, Okla.
Coffin, R. Clare, Denver, Colo.
Collingwood, D. M., Dallas, Tex.
Comstock, William S., Los Angeles, Calif.
Conkling, R. A., Oklahoma City, Okla.
||Cooper, Chalmer L., Norman, Okla.
Cooper, Herschel H., San Antonio, Tex.
||Copass, Jack M., Shawnee, Okla.
||Cordry, C. D., Fort Worth, Tex.
Cotner, Victor, Amarillo, Tex.
||Cox, Thomas S., Aspermont, Tex.
Cram, Ira H., Tulsa, Okla.
Crider, Albert F., Shreveport, La.
Crouse, George T., Hays, Kan.
Cullen, Ronald J., Tulsa, Okla.
Cunningham, Carleton J., Seguin, Tex.
||Curry, William H., Jr., San Antonio, Tex.
Curtice, A. Arthur, Los Angeles, Calif.

Dake, Charles L., Rolla, Mo.
Daniels, Harold G., Abilene, Tex.
Danvers, Don, San Antonio, Tex.
Davis, Elmer Fred, Glendale, Calif.
Davis, Thornton, Wichita Falls, Tex.
Dawson, Joseph M., San Antonio, Tex.
Dawson, William A., Woodward, Okla.
*Decker, Charles E., Norman, Okla.
DeFord, Ronald K., Roswell, N. M.
DeGolyer, E., New York, N. Y.
Denison, A. R., Fort Worth, Tex.
Deussen, Alexander, Houston, Tex.
De Wolf, Frank W., Houston, Tex.
||Dicken, Russell H., San Antonio, Tex.
Dickerson, Roy E., Maracaibo, Venezuela, S. A.
Disney, Orville A., San Antonio, Tex.
Dissinger, Earl, Houston, Tex.
Dobbin, Carroll E., Denver, Colo.
Donoghue, David, Fort Worth, Tex.
Donovan, Percy W., Minneapolis, Minn.
Dorsey, Geo. Edwin, Dallas, Tex.
||Douglas, L. A., Oklahoma City, Okla.
Dunn, George V., Tulsa, Okla.
Duston, Arthur W., Tulsa, Okla.

Eby, J. Brian, Houston, Tex.
Edson, Dwight J., San Angelo, Tex.
Eichelberger, O. H., Lake Charles, La.
Elliott, John E., Los Angeles, Calif.
Ellisor, Alva C., Houston, Tex.
Emch, John W., San Angelo, Tex.
||Emendorfer, Earl, Hammond, Ind.
Emrick, D. G., Houston, Tex.
English, Leon E., Lawton, Okla.
Esgen, W. K., Cisco, Tex.
Estergren, E. F., Fort Worth, Tex.
||Evans, Frank G., Jr., Tyler, Tex.

||Farrell, Agnes M., Washington, D. C.
Fenn, Ivan J., Austin, Tex.
||Ferrero, Clarence, Houston, Tex.
Finch, Elmer H., San Antonio, Tex.
Fletcher, Corbin D., Meridian, Miss.
Fohs, F. Julius, New York, N. Y.
Freedman, L. H., Fort Worth, Tex.
Fritts, Harold M., Mexia, Tex.
||Fulton, Loris J., Chickasha, Okla.
Fuqua, H. B., Fort Worth, Tex.

Galbraith, T. J., Alpine, Tex.
||Gallagher, William G., Abilene, Tex.
Gardner, James H., Tulsa, Okla.
Garner, Aubrey H., Montclair, N. J.
Garrett, Lovic P., Houston, Tex.
Garrett, Robert E., Tulsa, Okla.
Gester, Stephen H., San Francisco, Calif.
Getzendaner, Frank M., Uvalde, Tex.
||Gibbs, James F., Wichita Falls, Tex.
Giles, Albert W., Fayetteville, Ark.
Giles, John M., San Angelo, Tex.
Gillan, Silas L., Los Angeles, Calif.
Gilmour, Andrew, Fresno, Calif.
Goodrich, Raymond H., Houston, Tex.
Goodrich, Robert D., Fort Worth, Tex.
Gordon, Wallace, Azusa, Calif.
Graham, W. L., Okemah, Okla.
Gray, Alfred, Carlsbad, N. M.
||Gray, Shapleigh G., Shreveport, La.
Green, Guy E., Midland, Tex.
Greene, Frank C., Tulsa, Okla.
||Grigsby, Garland O., Shreveport, La.
Grigsby, R. B., Shreveport, La.
Griley, Horace L., Tulsa, Okla.
||Grim, Ralph E., University, Miss.
Grimm, Maurice W., Shreveport, La.
Griswold, Clyde T., Albuquerque, N. M.

Grogan, Samuel A., Tampico, Mexico
Gulley, M. Gordon, Pittsburgh, Pa.
Gunter, Herman, Tallahassee, Fla.

Hager, Dilworth S., Dallas, Tex.
Hagy, Lawrence R., Amarillo, Tex.
Hake, Benjamin F., Calgary, Alta., Canada
Hamm, W. Dow, Dallas, Tex.
Hammer, Alva A., Muskogee, Okla.
Hammill, Chester A., Dallas, Tex.
Hanna, G. Dallas, San Francisco, Calif.
Hanna, Marcus A., Houston, Tex.
||Hanson, Edwin V., Houston, Tex.
Harlowe, Leslie S., Shreveport, La.
Harlton, Bruce H., Tulsa, Okla.
Harris, Edwin S., Houston, Tex.
Hartley, Burton, San Antonio, Tex.
Hartman, Adolph E., San Antonio, Tex.
||Harvey, William W., San Antonio, Tex.
||Haseltine, Raymond H., Dallas, Tex.
Heald, K. C., Pittsburgh, Pa.
Heath, Francis E., Dallas, Tex.
Hedrick, O. F., Thurber, Tex.
Heidecke, Otto, Houston, Tex.
Heiland, Carl A., Golden, Colo.
Hennen, Ray V., Morgantown, W. Va.
Heroy, William B., White Plains, N. Y.
Herring, L. B., Fort Worth, Tex.
Hill, Harry B., Dallas, Tex.
Hoots, Harold W., Los Angeles, Calif.
Hoover, James E., Tulsa, Okla.
Hoover, William B., Amarillo, Tex.
Hopkins, Edwin B., New York, N. Y.
Hopkins, Oliver B., Toronto, Ont., Canada
Hopper, Walter E., Shreveport, La.
Hoskins, Baker, Jr., Laredo, Tex.
Hosterman, John F., San Angelo, Tex.
Housh, C. N., Houston, Tex.
Howe, Henry V., Baton Rouge, La.
Howeth, Irving K., Beeville, Tex.
||Huddleston, Arthur N., Brady, Tex.
Hudnall, James S., Coleman, Tex.
Hudson, William A., Fort Worth, Tex.
Hughes, Richard, Tulsa, Okla.
Hughes, Urban B., Wichita Falls, Tex.
||Hughes, Richard V., Baltimore, Md.
Hull, Joseph P. D., Tulsa, Okla.
Hummel, H. L., San Antonio, Tex.
Hunter, Paul B., Houston, Tex.
Hutson, E. B., Shreveport, La.
Hyde, Clarence E., Fort Worth, Tex.

Imbt, Robert F., San Angelo, Tex.
Israelsky, Merle C., Shreveport, La.
Ivy, John Smith, Shreveport, La.

Jay, Stanley E., San Antonio, Tex.
||Jenny, W. P., Houston, Tex.
||Johnson, E. L., Kenedy, Tex.
Johnson, J. Harlan, Golden, Colo.
Johnson, Roswell H., Pittsburgh, Pa.
Jones, Coy B., San Antonio, Tex.
Jones, Edward L., San Angelo, Tex.
Judson, Sidney A., Houston, Tex.

||Kamb, Hugo R., Allen, Okla.
||Kauenhowen, Walter, Shreveport, La.
||Kauffman, W. E., Wichita Falls, Tex.
Keith, Arthur, Washington, D. C.
Kelley, Ward W., San Antonio, Tex.
Kelly, Donald, Wichita Falls, Tex.
||Kemp, Harold S., Houston, Tex.
Kendrick, Frank E., Dallas, Tex.
Kernan, Thomas H., Dallas, Tex.
Kisling, James W., Jr., Shreveport, La.
||Kittredge, Frank R., Shawnee, Okla.
Knappen, Russell S., Tulsa, Okla.
Knebel, G. Moses, Palestine, Tex.
||Knox, T. K., Dallas, Tex.
||Koester, Edward A., Wichita, Kan.
Kolm, Robert N., Abilene, Tex.
Krampert, E. W., Parco, Wyo.

Lahee, Frederic H., Dallas, Tex.
Lang, W. B., Roswell, N. M.
Langworthy, A. A., Tulsa, Okla.
LaRue, James E., Houston, Tex.
Lauer, A. W., Tulsa, Okla.
||Lawton, Joe, Pawhuska, Okla.
Leach, Thomas W., Tulsa, Okla.
Leavenworth, Paul B., Houston, Tex.
Lee, Huylar W., San Angelo, Tex.
Lee, Lynn K., Tulsa, Okla.
Lee, Marvin, Wichita, Kan.
Lee, Wallace, Okmulgee, Okla.
Lester, O. C., Jr., Houston, Tex.
Levorsen, A. Irving, Tulsa, Okla.
Lewis, J. Whitney, Fort Worth, Tex.
Link, Theodore A., Calgary, Alta., Canada
Lloyd, Abe M., Wichita Falls, Tex.
Lloyd, E. Russell, Midland, Tex.
||Longnecker, Oscar M., Jr., Houston, Tex.
Longyear, Robert D., Minneapolis, Minn.
Lonsdale, John T., College Station, Tex.

MacDonell, James A., Lima, Ohio
||Maley, Vaughn C., McCamey, Tex.
Maley, W. A., Corpus Christi, Tex.
Markley, Elmer A., Tulsa, Okla.
||Markley, Joseph H., Jr., Wichita Falls, Tex.
Martin, George C., Adams, Mass.
||Martyn, Phillip F., Houston, Tex.
Mason, Shirley L., Pittsburgh, Pa.
Masterson, Reba B., San Antonio, Tex.
||Mathes, Donald E., Dallas, Tex.
||McCarter, W. Blair, Houston, Tex.

McCaskey, Morgan E., Fort Worth, Tex.
McClellan, Hugh W., Tulsa, Okla.
||McClintock, Charles B., Oil City, Pa.
McCluer, R. D., Houston, Tex.
McCollom, C. R., Los Angeles, Calif.
McCollom, Leonard F., San Antonio, Tex.
||McCutchin, John A., Norman, Okla.
McDermott, Eugene, Houston, Tex.
McDonald, Worth W., Wichita Falls, Tex.
||McFarland, Paul W., Dallas, Tex.
McFarland, R. S., Tulsa, Okla.
McFerron, George I., Tulsa, Okla.
McGaha, Charles P., Wichita Falls, Tex.
McLellan, Hiram J., Tyler, Tex.
McLeod, Angus, Dallas, Tex.
McNutt, Vachel H., San Antonio, Tex.
Mershon, Milton M., Clarksville, Ark.
Millar, John E., Jr., Tulsa, Okla.
Miller, David B., Fort Worth, Tex.
Miller, E. Floyd, Tulsa, Okla.
Miller, Forrest J., Wichita, Kan.
Miller, Guy E., Long Beach, Calif.
Miller, John C., Houston, Tex.
Mills, Coe S., Fort Worth, Tex.
Minor, H. E., Houston, Tex.
Moncrief, E. C., Wichita, Kan.
Monnett, V. E., Norman, Okla.
||Monsour, Eli T., Houston, Tex.
Moody, Clarence L., Shreveport, La.
Moody, Graham E., Dallas, Tex.
Moore, Hastings, Tulsa, Okla.
Moore, Raymond C., Lawrence, Kan.
Moran, Robert B., Los Angeles, Calif.
||Moreman, W. L., Lawrence, Kan.
Morgan, Frank A., Los Angeles, Calif.
Morgan, L. C., Wichita, Kan.
Morris, A. Ferd, Bartlesville, Okla.
||Morrison, T. E., Houston, Okla.
Mosburg, Lewis G., Tulsa, Okla.
Mossom, Stuart, Shreveport, La.
Moulton, Gail F., Meridian, Miss.
Moyse, Nathan I., Tulsa, Okla.
Muir, John M., Dallas, Tex.
||Mullins, William B., San Antonio, Tex.
Munroe, Donald J., Jackson, Miss.
||Murchison, Eugene A., Jr., McCamey, Tex.
Murphy, P. C., Houston, Tex.
Myers, John C., Houston, Tex.
Myers, Julian Q., San Antonio, Tex.

||Nance, Albert G., Fort Worth, Tex.
Nash, Howard F., Calgary, Alta., Canada
Nelson, Jean O., El Dorado, Ark.
Nelson, Wilbur A., Charlottesville, Va.
Neumann, L. Murray, Tulsa, Okla.
Newby, Jerry B., Oklahoma City, Okla.
Newman, Thomas F., Amarillo, Tex.
Nicholls, William M., Wichita Falls, Tex.
Nichols, C. R., Dallas, Tex.
Noble, Homer A., Houston, Tex.
North, Lloyd, Houston, Tex.
||Norton, Richard D., Shreveport, La.
Nowlan, Harry H., Tulsa, Okla.

Obering, Ernest A., Carlsbad, N. M.
Oldham, Albert E., San Antonio, Tex.
||Oliphant, A. G., Tulsa, Okla.
Olson, Walter S., Cartagena, Colombia, S. A.
Orynski, Leonard W., Dallas, Tex.
Owen, Edgar W., San Antonio, Tex.
Owens, Frith C., McAllen, Tex.

Pack, R. W., Beaumont, Tex.
Packard, Henry J., Denver, Colo.
Packard, Sidney A., Shreveport, La.
||Palmer, Joe C., San Antonio, Tex.
Paxson, Roland B., Houston, Tex.
Perrine, Irving, Oklahoma City, Okla.
||Pettigrew, Virgil, Wichita Falls, Tex.
Petty, T. F., Roswell, N. M.
Phillips, E. Douglas, Baton Rouge, La.
Plummer, F. B., Austin, Tex.
Pogue, Joseph E., New York, N. Y.
Ponton, G. M., Tallahassee, Fla.
Porch, Edwin L., Jr., San Antonio, Tex.
||Postley, Olive C., Washington, D. C.
Potter, Grover C., Tulsa, Okla.
Poulsen, Frank E., Greenville, Tex.
Powell, Ralph S., Wichita Falls, Tex.
Powers, Sidney, Tulsa, Okla.
Pratt, Wallace E., Houston, Tex.
Preece, Rae, Tulsa, Okla.
Preston, John Basil, Glasgow, Ky.
Price, W. Armstrong, Houston, Tex.

Quilliam, William, Beaumont, Tex.

Rankin, Charles L., Lake Charles, La.
Reed, Ralph D., Alhambra, Calif.
||Reed, Warren B., Morgan City, La.
Reeside, John Bernard, Jr., Hyattsville, Md.
Reid, Robert P., Bartlesville, Okla.
Renick, B. Coleman, Dallas, Tex.
Rettger, Robert E., San Angelo, Tex.
Reynolds, Roy A., Fort Worth, Tex.
Rich, John L., Ottawa, Kan.
Richards, A. Howard, Oklahoma City, Okla.
Richards, J. T., Oklahoma City, Okla.
Richards, Ralph W., Washington, D. C.
Richardson, G. B., Washington, D. C.
Riggs, Robert J., Bartlesville, Okla.
Roberts, Louis C., Jr., San Antonio, Tex.
Robinson, B. F., Cameron, Tex.
Robinson, Heath M., Dallas, Tex.

||Rolshausen, F. W., Houston, Tex.
Romine, Thomas B., Fort Worth, Tex.
||Rook, Stephen H., Shreveport, La.
Roop, Charles W., Bartlesville, Okla.
Ross, John S., Shreveport, La.
Rothrock, Howard E., Tulsa, Okla.
Row, Charles H., San Antonio, Tex.
Ruby, Glen M., Vancouver, B. C.
Rusk, Willard W., Tulsa, Okla.
Russ, Leon F., Dallas, Tex.
Russell, P. G., Eastland, Tex.
Ryan, Russell F., Freeport, Ill.

Sackett, H. F., Tulsa, Okla.
Samuell, J. Howard, Coleman, Tex.
Sands, J. M., Bartlesville, Okla.
||Sargent, E. C., Austin, Tex.
||Saville, Wilson G., Houston, Tex.
Sawtelle, George, Houston, Tex.
Schneider, G. W., Shreveport, La.
Scholl, Louis A., Jr., Houston, Tex.
Schoolfield, R. F., San Antonio, Tex.
Schouten, Franklin H., Tyler, Tex.
Schumacher, J. P., Houston, Tex.
||Schweer, Harry F., Oklahoma City, Okla.
Schwennesen, Alvin T., Houston, Tex.
Scott, Gayle, Fort Worth, Tex.
Scott, H. M., Tulsa, Okla.
Scudder, E. W., Denver, Colo.
Sealey, Fred C., Houston, Tex.
Seashore, Paul T., Houston, Tex.
||Self, Selden R., Midland, Tex.
Selig, A. L., Fort Worth, Tex.
Sellards, E. H., Austin, Tex.
Semmes, Douglas R., San Antonio, Tex.
||Shakley, Ed., St. Louis, Mo.
Shaw, Everett S., Denver, Colo.
Shayes, Fred P., Beeville, Tex.
Shea, E. F., Tulsa, Okla.
Shearer, Harold K., Shreveport, La.
Shutt, Roscoe E., St. Louis, Mo.
Singewald, Quentin D., Rochester, N. Y.
Smiley, H. F., Wichita Falls, Tex.
Smith, Richard A., Lansing, Mich.
Snider, George W., Wichita, Kan.
Snider, L. B., Tulsa, Okla.
Snider, L. C., New York, N. Y.
Snow, Dale R., Tulsa, Okla.
Snyder, John Y., Shreveport, La.
Somers, R. E., Pittsburgh, Pa.
Spieker, Edmund M., Columbus, Ohio
||Sprague, William B., Corsicana, Tex.
Stacy, Dean M., Oklahoma City, Okla.
Stathers, Silas C., Shreveport, La.
Stearn, Noel H., St. Louis, Mo.
Steiner, George, Houston, Tex.
Steinmayer, R. A., New Orleans, La.
Stevens, G. R., Shreveport, La.
Stiles, Elisabeth, Houston, Tex.
Stiller, Ernest A., Shreveport, La.
Storm, Lynn W., Austin, Tex.
Storm, Willis, Dallas, Tex.
Suman, John R., Houston, Tex.
Sundt, O. F., Houston, Tex.
Swiger, Rual B., San Antonio, Tex.

Taff, Joseph A., San Francisco, Calif.
||Tanner, Hugh A., San Antonio, Tex.
||Tarver, Kathleen, Fort Worth, Tex.
||Tatum, Emmett P., Jr., Houston, Tex.
Teas, L. P., Houston, Tex.
Terrill, J. V., Amarillo, Tex.
Thom, W. T., Jr., Princeton, N. J.
Thomas, C. R., Tulsa, Okla.
Thomas, George Dewey, St. Louis, Mo.
Thomas, J. Elmer, Fort Worth, Tex.
Thomas, Norman L., Fort Worth, Tex.
Thomas, William A., Saginaw, Mich.
Thompson, B. E., Fort Worth, Tex.
Thompson, Evan G., Houston, Tex.
Thompson, Sheridan A., Houston, Tex.
Thompson, Wallace C., Tyler, Tex.
Thornburgh, H. R., Dallas, Tex.
Tomlinson, Charles W., Ardmore, Okla.
Tong, James A., Baltimore, Md.
Trager, Earl A., Tulsa, Okla.
Trask, Parker D., Princeton, N. J.
Trowbridge, Arthur C., Iowa City, Iowa
Truex, Arthur F., Tulsa, Okla.
Turner, Joseph H., San Antonio, Tex.

||Upson, M. E., Fort Worth, Tex.

Vanderpool, Harold C., Eagle Pass, Tex.
Van Tuyl, Francis M., Golden, Colo.
||Van Zant, James H., Enid, Okla.
Vetter, John M., Houston, Tex.
||Vickery, Ward R., Wichita, Kan.
Vorbe, Georges, Midland, Tex.

Wagener, Charles H., San Antonio, Tex.
||Waggoner, Stephen Gose, Wichita Falls, Tex.
Waring, Gerald A., Tulsa, Okla.
||Warren, Howard C., Bartlesville, Okla.
Wasson, Isabel B., River Forest, Ill.
Wasson, Theron, Chicago, Ill.
Waters, James A., Dallas, Tex.
Watson, C. P., Fort Worth, Tex.
Weaver, Paul, Houston, Tex.
Weeks, Albert W., San Antonio, Tex.
||Weeks, Warren B., Oklahoma City, Okla.
Weinzierl, John F., Houston, Tex.
Weirich, T. E., Tulsa, Okla.
Wells, Lloyd E., Wichita Falls, Tex.
Wendlandt, E. A., Tyler, Tex.

Westby, Gerald H., Bartlesville, Okla.
Wheeler, Orby Clinton, Toronto, Canada
Whisenant, John B., Big Spring, Tex.
Whitcomb, Bruce, Fort Worth, Tex.
White, Luther B., Tulsa, Okla.
White, Maynard P., Ardmore, Okla.
Whitney, F. L., Austin, Tex.
Whitwell, E. V., Jackson, Miss.
Wilcox, Fred H., San Angelo, Tex.
||Williams, Francis S., McPherson, Kan.
Williston, Samuel H., Dallas, Tex.
Wilson, Joseph M., Dallas, Tex.
Wilson, Walter B., Tulsa, Okla.
Wolf, Albert G., Houston, Tex.
Woods, Sam H., Ardmore, Okla.
Woodward, Harold Robinson, Wichita, Kan.
Woolnough, W. G., Canberra, F. C. T., Australia
Woolsey, E. V., Luling, Tex.
Wrather, William E., Dallas, Tex.
Wright, Andrew C., Tyler, Tex.

Yager, Charles E., Fort Worth, Tex.
Yoakam, Coler A., Tulsa, Okla.
||Young, Karl E., Sulphur, La.

Zavoico, Basil B., Tulsa, Okla.

## MINUTES, FIFTEENTH ANNUAL BUSINESS MEETING ROOSEVELT HOTEL, NEW ORLEANS, LOUISIANA MARCH 22, 1930

R. S. McFARLAND, *presiding, vice* J. Y. SNYDER

Past-president McFarland called the meeting to order at 9:30 A. M.

The minutes of the fourteenth annual meeting were not read, by unanimous consent.

The report of president Snyder was read by Luther H. White, who prefaced the reading by a few remarks in appreciation of Mr. Snyder's work for the Association and his presence at the meeting contrary to medical advice.

### REPORT OF THE PRESIDENT

My remarks, from necessity and inclination, will be brief. My predecessors in office have related our past history, of which we are justly proud.

The progress of the Association during the present administration will be fully reviewed in the reports of our second and third vice-presidents, respectively in charge of finance and editorial work.

These reports cover fully the happenings of the fifteenth year of our existence and advancement. The future of the Association, which lies with that of the oil business, does not seem as promising as it has been at times in the past. Last year's president called attention to the unfavorable condition of the oil business. Since then there has been a change. It has become worse. Overproduction—too much oil. The present unsatisfactory conditions are working hardships on many, but the oil business is not alone in its depression. Other lines of business dealing with the production of raw materials are in a similar condition from the same cause—overproduction.

Due to the advances in geological knowledge and to the efforts and success of the petroleum geologists in applying this knowledge, to the economic application of physics to the problem of finding favorable conditions for the accumulation of oil, and to mechanical improvements which insure greater production possibilities, we now have assurance of oil resources much in excess of the most optimistic estimates of a few years ago.

Orderly methods and intelligent guidance are bringing the oil business out of chaos. Improvement is certainly not far off. We have only to do our part tending to the profit of the industry and incidentally our own. Our future is more encouraging than it seems.

Our Association shows a healthy growth. The increase in membership during the present administration has been approximately the same as it was during the previous year.

Probably the most serious duty the executive committee has to perform is that of passing on the qualifications of those applying for membership, and the most serious responsibility which a member has is that of sponsoring applications for membership. That this responsibility is taken with its deserved seriousness is evidenced by the fact that few applicants need to be refused. After an application is received, a follow-up inquiry blank is mailed to each sponsor requesting more detailed information than it is possible to obtain from the application. Too often these blanks are neglected or do not bring the additional detailed information needed in order that the members of the executive committee may reach a final and proper decision. Very often a sponsor will reply curtly. The inquiries deserve to be answered in the spirit and with the thought which prompts their sending.

It has been suggested that our district representatives do not function as fully as they might. This is not mentioned in a spirit of criticism, but with the idea that thought be given to this and that they work out among themselves something looking toward more constructive efforts throughout the year, efforts which would lead to a better understanding of the problems to come before the business committee when it meets at our annual convention.

I wish to thank the other members of the executive committee and our business manager for their support and untiring efforts. To them should be given full credit for whatever success the present administration can point to.

I thank you for the great honor which was conferred on me and hope and believe, having in a measure learned the job, that I can render more and better service as a member of the executive committee during the next administration, where I will serve by reason of being your past-president.

I thank you.

JOHN Y. SNYDER, *President*

Second vice-president Denison, in charge of finances, presented his annual report.

REPORT ON MEMBERSHIP

*Growth*

A list of members as of March 1, 1930, appears in the March, 1930, *Bulletin*. This year the entire membership has been arranged alphabetically with an appropriate symbol for each class of membership. This change greatly simplifies the location and identification of members. A new feature has been added to the membership list, namely, the date of election to membership. This number refers to the date of entry into the Association, whether as an Associate or Active member.

During the past twelve months the Association has suffered the loss by demise of eight members, as follows.

| | |
|---|---|
| M. Wood Stanley | Harry H. Wilson |
| Rudolf R. Pollok | Rudolf R. Brandenthaler |
| Frank P. Latimer | Maurice B. Schmittou |
| Paul Franklin Morse | Irving V. Augur |

Loss in membership from other causes totaled 40. The net gain in membership for the period is 166 as compared with 174 for the similar preceding period. The number of applicants elected or with applications pending is 209 compared with 170 the previous year. Total membership now numbers 2,292, of which 1,683 are active members and 602 are associate members. The total number of associate members shows a decrease as compared with the previous year, which reflects the increasing number of transfers to active membership and larger number of applicants with qualifications for the higher class of membership.

These figures point to a steady and continued growth, while the high standards and principles of the Association have been maintained. Following are statistics reflecting the growth in membership through the history of the Association and a comparison of the past two years.

*Membership of the Association*

| | |
|---|---|
| Number of members May 19, 1917 (first published list) | 94 |
| Number of members February 15, 1918 | 176 |
| Number of members March 15, 1919 | 210 |
| Number of members March 18, 1920 | 392 |
| Number of members March 15, 1921 | 621 |
| Number of members March 8, 1922 | 767 |
| Number of members March 20, 1923 | 901 |
| Number of members March 20, 1924 | 1,080 |
| Number of members March 21, 1925 | 1,253 |
| Number of members March 20, 1926 | 1,504 |
| Number of members March 1, 1927 | 1,670 |
| Number of members March 1, 1928 | 1,952 |
| Number of members March 1, 1929 | 2,126 |
| Number of members March 1, 1930 | 2,292 |

| *Comparative Data* | *March 1 1929* | | *March 1 1930* | |
|---|---|---|---|---|
| Number of honorary members | 6 | | 7 | |
| Number of active members | 1,496 | | 1,683 | |
| Number of associate members | 624 | | 602 | |
| Total number of members | | 2,126 | | 2,292 |
| Increase in membership | | 174 | | 166 |
| Applicants elected, dues unpaid | 44 | | 35 | |
| Applications approved for publication | 60 | | 89 | |
| Recent applications | 66 | | 85 | |
| Total applications on hand | | 170 | | 209 |

| | | | | |
|---|---|---|---|---|
| Applications for transfer approved, dues unpaid | 23 | | 9 | |
| Applications for transfer approved for publication | 54 | | 13 | |
| Recent applications for transfer | 17 | | 12 | |
| Total applications for transfer on hand | | 94 | | 34 |
| Number of members withdrawn | 16 | | 18 | |
| Number of members dropped | 33 | | 46 | |
| Number of members died | 8 | | 8 | |
| Total loss in membership | | 57 | | 72 |
| Number of members in arrears, previous year | 62 | | 78 | |
| Active members in arrears, current year | 474 | | 600 | |
| Associate members in arrears, current year | 247 | | 243 | |
| Total number of members in arrears | | 721 | | 843 |

*Circulation of the Bulletin*

| | | | | |
|---|---|---|---|---|
| 1. Subscriptions (non-members) | | | | |
| Libraries | 129 | | 142 | |
| Companies | 71 | | 80 | |
| Individuals | 66 | | 52 | |
| Total non-member subscribers | | 266 | | 274 |
| 2. Exchanges, etc. | | 73 | | 79 |
| 3. Association members | | 2,126 | | 2,292 |
| Total monthly circulation of *Bulletin* | | 2,465 | | 2,645 |

It is desired to call the attention of the members to the increase in the number of delinquent dues both for last year and the current year. There were 126 more active members delinquent for current dues on March 1, 1930, than at the same time in 1929. There were 16 more members delinquent for the previous year's dues on March 1, 1930, than in 1929. The reduction in the total number of associate members on March 1, 1930, seems to have enabled that class to have four fewer members in arrears for current dues than at the same time in 1929. It is urged that the members give more careful thought to prompt payment of dues in order that the Association may function unhampered.

*Distribution*

Thirty-nine states and thirty foreign countries contribute members to the Association. Approximately 90 per cent of the members live within the United States. Within the states, Texas leads with 657 or 29 per cent, Oklahoma is second with 521 or 24 per cent, California third with 298 or 13 per cent, and Kansas fourth with 95 or 4 per cent. These four states have a total of 1,571 or approximately 70 per cent of the entire membership. Herewith is given the complete distribution by states and countries.

*Geographic Distribution of A. A. P. G. Members*

UNITED STATES

| | | | |
|---|---|---|---|
| Texas | 657 | Montana | 6 |
| Oklahoma | 521 | Minnesota | 5 |
| California | 298 | Maryland | 4 |
| Kansas | 95 | Nebraska | 4 |
| New York | 87 | Utah | 4 |
| Louisiana | 57 | Connecticut | 4 |
| Colorado | 55 | Alabama | 3 |
| Pennsylvania | 44 | Indiana | 3 |
| New Mexico | 25 | Iowa | 3 |
| Illinois | 23 | Tennessee | 3 |
| Missouri | 23 | Virginia | 3 |
| District of Columbia | 19 | Washington | 3 |
| Ohio | 17 | Wisconsin | 3 |
| Wyoming | 14 | Arizona | 2 |
| Kentucky | 12 | Florida | 2 |
| Michigan | 12 | Oregon | 2 |
| Arkansas | 11 | South Dakota | 2 |
| Mississippi | 11 | Nevada | 1 |
| West Virginia | 9 | | |
| Massachusetts | 8 | Total, United States | 2,063 |
| New Jersey | 8 | | |

FOREIGN

| | | | |
|---|---|---|---|
| Venezuela | 49 | Australia | 3 |
| Mexico | 37 | Angola | 2 |
| Canada | 24 | Austria | 2 |
| Holland | 13 | New Zealand | 2 |
| England | 12 | Algeria | 1 |
| Switzerland | 9 | Belgium | 1 |
| Argentina | 8 | British Somaliland | 1 |
| Colombia | 8 | Chile | 1 |
| France | 8 | Cuba | 1 |
| Dutch East Indies | 8 | Ecuador | 1 |
| Japan | 5 | Egypt | 1 |
| Roumania | 5 | India | 1 |
| Germany | 4 | Scotland | 1 |
| Peru | 4 | Turkey | 1 |
| Trinidad | 3 | | |
| U. S. S. R. | 3 | Total, Foreign | 219 |
| | | Address Unknown | 10 |
| Grand Total | | | 2,292 |

## Report on Finances

*Annual Audit*

A complete audit of books and property of the Association for the fiscal year 1929 is published in the March *Bulletin*. A study of the balance sheet (page 341) under assets shows that all significant items increased over 1928; the largest gain was in inventories of printed matter on hand, which was $4,887.46. The increase was largely due to the publication during 1929 of 1,000 additional copies of the *Bulletin* for use in bound volumes and as a reserve for back numbers. Cash in the bank increased $4,694.34 to the signifi-

cant figure of $9,361.46. Concurrently with this gain, investments were increased $1,032.17. Total assets increased from $47,341.73 to $61,757.60.

Exhibit *C* of the audit (page 347) gives a comparative statement of income and expenses of the general fund, for the years 1928 and 1929. Significant items under income which decreased in 1929 are

| | |
|---|---|
| Associate membership dues | $ 196.00 |
| Sale of bound volumes | 311.38 |
| Sale of back numbers | 521.47 |

Significant items under expense which increased in 1929 are

| | |
|---|---|
| Cost of printing *Bulletin* | $7,991.30 |
| Editorial secretary | 358.24 |
| Clerical salaries | 561.81 |

The decrease in items of income and increase in expenditures have combined to cause a decrease in net income in 1929 over 1928 of $3,321.13.

The largest increase in expense is in printing the *Bulletin*. This is due in part to the printing of additional copies in 1929, but in a greater degree to the increase in the number of printed pages in the *Bulletin*. Volume 13 (1929) has 1,612 pages as compared with 1,204 in Volume 12 (1928), an increase of 33 per cent. No better criterion for the ability to give increasing service to the members can be offered than the foregoing fact. While rendering the large additional service as noted, and in spite of the decrease as compared with 1928, the Association business still reflects a safe balance of income over expenses amounting to $6,836.37.

*Sale of Publications*

The publication fund shows a profit in 1929 of $1,666.46 as compared with a deficit during the preceding year of $884.04. This difference was largely due to the phenomenal sale of Volume I, *Structure of Typical American Oil Fields*. The first edition, consisting of 1,500 copies, was sold in less than 12 months; a second edition of 1,000 copies has been printed to take care of the continued demand. Volume II came from the press in December, 1929, and the demand for this volume seems to be as great as for Volume I. During the year the volume on *Geology of Salt Dome Oil Fields* was completely exhausted.

*Association Funds*

It is desired to remind the membership that the Association has three distinct funds, namely: General Fund, Revolving Publication Fund, and Research Fund.

The General Fund is derived from membership dues, subscription to the *Bulletin*, sale of back numbers, indexes, bound volumes, and the salt-dome volume. This fund constitutes practically the sole support of the Association. From it must be paid all expenses for printing and distributing the *Bulletin*, and all general and office expenses and donations to affiliated societies. In order that any member may be able to compare at a glance the relative importance of the sources of revenue and disbursements, the following tables have been prepared.

SOURCE OF THE ASSOCIATION'S DOLLAR, 1929

| | |
|---|---|
| Dues, Active Members | $.48 |
| Dues, Associate Members | .14 |
| Life Memberships | .01 |
| Subscriptions to the *Bulletin* | .09 |
| Sale of Back Numbers and Salt-Dome Volume | .10 |
| Revenue from Advertisements | .14 |
| Interest on Investments | .04 |
| | $1.00 |

WHAT WAS DONE WITH THE ASSOCIATION'S DOLLAR, 1929

| | |
|---|---|
| Cost of Printing *Bulletin* | .51 |
| Salaries (Business Manager and Clerical) | .23 |
| Office Expenses | .10 |
| Donated to Affiliated Society | .02 |
| Invested | .14 |
| | $1.00 |

The most significant feature of these figures is that membership dues, both associate and active, amount to only 62 cents, while the expenses, which are almost exclusively concerned with what the membership receives in the *Bulletin*, total 84 cents. The members, therefore, receive material which costs 22 cents more to produce than they contribute. This favorable ratio is only maintained by other sources of revenue which the Association has at its disposal. One of the largest of these sources is advertising, which, through the energy of Mr. Hull, showed a substantial increase in 1929.

The Revolving Publication Fund was established by a voluntary contribution from a local group of members. It is in no way a part of the Association's working funds. The Association acts as trustee of the fund, which can be used only for the financing of special publications. The income from the sale of such publications is returned to the publication fund, as well as any profit accruing from such sale. The volumes which have been financed in whole or in part by this fund are

*Theory of Continental Drift, A Symposium*
*Structure of Typical American Oil Fields*, Vol. I
*Structure of Typical American Oil Fields*, Vol. II

Each of these volumes has been offered to the members at cost plus distribution. They are offered to non-members at an advance in price sufficient to give reasonable profit on the cost. This feature offers a safeguard against possible loss to the publication fund due to unforeseen cost items or failure to sell a complete edition. The custody of this fund has enabled the Association to furnish the members with three volumes of outstanding contributions to geology at a large saving. During the early part of 1930 the fund was increased by a donation of $900.00 from the Fort Worth Geological Society.

The Research Fund, like the Publication Fund, is one for which the Association is trustee. Unlike the Publication Fund, it can be entirely disbursed by the executive committee. Accessions to this fund are by voluntary contributions and the account is maintained separate and distinct from both the General and the Revolving Publication Fund.

*Funds Available*

It has been customary for a number of years to present at the time of the annual meeting a statement showing the funds on hand at the moment. Obviously since the Association collects all dues early in the year for expenditures throughout the year, such a statement can in no way reflect the financial condition of the Association or indicate its prospects for the complete year. It does, however, show by a comparison with a similar statement of the previous year the relative temporary conditions. Such a comparison follows.

| | *March 1, 1929* | | *March 1, 1930* | |
|---|---|---|---|---|
| **GENERAL EXPENSE FUND** | | | | |
| Checking account | $ 5,159.86 | | $ 6,047.41 | |
| Interest-bearing account | 10,000.00 | | 10,000.00 | |
| Total current funds available | | $15,159.86 | | $16,047.41 |
| **INVESTMENT FUND** | | | | |
| Interest-bearing bonds | | 28,133.75 | | 27,599.45 |
| **PUBLICATION FUND** | | | | |
| Checking account | $ 2,322.09 | | $ 1,383.11 | |
| Interest-bearing account | 1,937.39 | | | |
| Total publication funds available | | 4,259.48 | | 1,383.11 |
| **RESEARCH FUND** | | | | |
| Interest-bearing account | | 190.00 | | 663.86 |
| **LIFE MEMBERSHIP FUND** | | | | |
| Interest-bearing account | | ..... | | 600.00 |
| Total funds on hand | | $47,743.09 | | $46,293.83 |

An item of increase is that in "current funds available," which is nearly $1,000.00 greater than last year. This, however, is about balanced by a decrease in the total amount of "interest-bearing bonds." The Publication Fund shows a marked decrease which is due to the financing of Vol. II, *Structure of Typical American Oil Fields*. The decrease in this fund is great enough to overcome additions made to the Research Fund and the money in the Life Membership Fund, thereby making "Total Funds on Hand" $1,449.26 less than last year.

In summary it may be said that the Association registered substantial gains both in membership and in finance; at the same time it has rendered larger and broader service to each individual member, to petroleum geology, and to science in general.

A. R. DENISON,
*Second vice-president in charge of finances*

Third vice-president Lahee, in charge of editorial work, read his annual report.

## Report on Editorial Work

During the past year no radical changes have been made in the management and the routine of the editorial work of the Association. Mr. Hull and his staff have ably conducted the many details of the preparation and printing of the *Bulletin*. In this connection the editor has served largely in an advisory capacity.

I want to take this opportunity to remind the members of the particular importance of the *Bulletin* to them and to the Association. This publication not only reaches all our members but also is distributed far and wide in foreign countries. Through it we keep in touch with one another and make contact with the outside technical world. There is no other interest in our Association of such wide appeal and general usefulness. It is a commentary on our activities, the expression of our aims. It is our main channel for coöperation.

To a very great extent the *Bulletin* is your achievement. In it every member should feel a just pride and a definite responsibility. It includes several departments to one or another of which you can all contribute from time to time. For the department headed "Discussion" let us have your views and criticisms of articles by other authors. For the department on "Geological Notes" let us have brief descriptions of features which you think are of sufficient interest to tell your geological friends. Above all, I would remind you always carefully to read the pages devoted to the Association Round Table. Too often members assert that they have not heard of certain Association affairs, although, as a matter of fact, these affairs have been printed in the Round Table for the consideration of the whole membership. Particularly it is your duty to read over the list of applicants for membership whenever such a list is published in the Association Round Table. If you know of reasons for denying membership to any applicant, do not hesitate to communicate with Mr. Hull or with any of the executive officers. Let us all help to make the *Bulletin* serve its various purposes.

Do not forget that we have regional associate editors whose pleasure it will be to assist you in preparing manuscripts, and who can often help you with pertinent advice. And I trust that these associate editors will not overlook the fact that they should be continually on the watch for subject matter and news items for the *Bulletin*, and also for promising young authors.

By way of analysis, I may say that during 1929 the *Bulletin* contained 1,612 pages as compared with 1,204 pages in 1928. In 1929 we published 61 major articles; in 1928, 48. In 1929 we printed 22 geological notes compared with 19 in 1928. Of the major articles in 1929, 3 were on general topics; 14 were on theoretical subjects and experimental results; 2 referred to paleontology; 4 to geophysics; 3 to foreign fields; and, bearing upon general stratigraphy or geological structure, there were 21 papers concerning the southern Mid-Continent area, 5 on the northern Mid-Continent states, 5 on the Rocky Mountain states, and 4 on the Pacific Coast area.

In August, 1929, we began a new department on "Research Notes." This is intended to function as a clearing house for brief reports and statements from our research committee, for suggestions from any of the Association members regarding problems worthy of research, and for reports of progress on research investigations under the auspices of the Association. This department needs more support.

The outstanding event of 1929 in the way of publication was the appearance of the two volumes of *Structure of Typical American Oil Fields*. Volume I came off the press in March, and Vol. II in December. Here I want to repeat what Mr. Rich said to you last year, that to Sidney Powers belongs a large amount of the credit for compiling and completing this valuable compendium of knowledge.

At this annual meeting, for the first time, the technical program has been in charge of the editorial staff of the Association instead of under a local committee. To the associate editors and the members of special committees appointed for soliciting papers on selected subjects, I want to express my warm appreciation of their efforts. To the many authors of our program we all owe a special debt of gratitude for a most interesting and instructive group of papers. My only regret is that in our earnest desire to give as many authors as possible opportunity to present their contributions, we have felt obliged to limit all papers to but a few minutes for presentation. Where contributions have thus been unduly abbreviated, we shall all look forward to reading them in full in the *Bulletin*.

FREDERIC H. LAHEE,
*Third vice-president in charge of editorial work*

The ballot committee reported and the results of the election for officers were read by past-president McFarland.

REPORT OF BALLOT COMMITTEE

Nominations for officers of the Association were made in open meeting, Thursday afternoon, the first day of the meeting. Ballot boxes were open all day Friday. Total ballots cast, 415.

| | | |
|---|---|---|
| *For president,* | SIDNEY POWERS | 244 |
| | DAVID DONOGHUE | 171 |
| *For first vice-president,* | R. D. REED | unan. |
| *For second vice-president,* | MARVIN LEE | 233 |
| | J. M. SANDS | 173 |
| *For third vice-president,* | F. H. LAHEE | unan. |

*Ballot committee,* M. G. CHENEY, *chairman*
H. B. FUQUA — WALLACE C. THOMPSON
RICHARD HUGHES — WILLIS STORM

A. F. Crider read the report of the resolutions committee.

REPORT OF RESOLUTIONS COMMITTEE

*Be it resolved*, that we express our appreciation and thanks to the following who have contributed to the success of the fifteenth annual meeting in New Orleans.

1. The Roosevelt Hotel, Mr. Seymour Weiss, assistant manager, for the courteous and efficient service which the hotel has rendered the Association in connection with this meeting.

2. The New Orleans Convention and Publicity Bureau, represented by Mr. Sam Fowlkes, and the New Orleans Association of Commerce, represented by Mr. Howard S. Greene, who have had charge of arranging the details of the meeting which have been carried out so efficiently.

3. Mr. R. A. Steinmayer, professor of geology at Tulane University. Professor Steinmayer is the only member of the Association living in New Orleans, and on him has largely rested the burden of arranging and planning many of the details of this meeting.

4. The Louisiana Gas and Fuel Company, the Standard Oil Company of Louisiana, the Louisiana Oil Refining Corporation, the Arkansas Natural Gas Corporation, and the Triangle Drilling Company, all of Shreveport, Louisiana, who have so generously contributed to the expenses incurred in connection with the meeting.

5. The Louisiana Land and Exploration Company, through Mr. Frank W. DeWolf, and The Texas Company, through Mr. R. C. Stewart, for the courtesies they have rendered in connection with the special trip through the Terrebonne salt-dome development area.

6. The Shreveport Geological Society, Mr. M. W. Grimm, president, and the various committees who have assisted Mr. J. Y. Snyder, president of the Association, in making this one of the most successful meetings that the Association has ever enjoyed.

7. Mr. H. C. Ferrell and Mr. Warren Coons, of the Standard Oil Company at New Orleans, who have arranged and carried into execution the golf tournament which was enjoyed by all who participated; and the officials of the Audubon Club, through whose courtesy the club and the course were made available.

*Be it resolved*, that we express our appreciation and thanks to the Fort Worth Geological Society for the recent contribution which it has made to the extent of $900.00 to the Revolving Publication Fund of the Association.

*Whereas*, one of our oldest and most loyal members, W. C. Spooner, of Shreveport, on account of serious illness, has been unable to attend the meeting,

*Be it resolved*, that we express our regret that he has been unable to be present, and tender him our best wishes for his speedy recovery.

*Be it resolved*, that these resolutions be spread upon the records of the Association, and that a copy of each specific resolution be mailed to the individuals, societies, organizations, and companies mentioned.

The resolutions were unanimously adopted.

*Resolutions committee*, JAMES H. GARDNER, *chairman*
A. F. CRIDER
R. E. RETTGER

Upon request of Mr. McFarland, Wallace E. Pratt, chairman of the general business committee, took the chair and presented the recommendations for action of the Association.

REPORT OF BUSINESS COMMITTEE

(The recommendations by the committee are in the form of resolutions unanimously carried by the Association.)

1. *Annual meeting date*

*Moved*, that the date of the annual meeting be not changed.

2. *Mississippi River flood control*

*Whereas*, the American Association of Petroleum Geologists in convention assembled at New Orleans realizes the importance of a correct and adequate solution of the problem of flood control in the lower Mississippi River Basin, and

*Whereas*, this solution is vital to an important and growing section of our country, and

*Whereas*, this Association considers it important to assemble all of the scientific facts bearing on this problem, both geologic and otherwise;

*Be it resolved*, by the American Association of Petroleum Geologists in convention assembled, that it favors the expansion of the present Mississippi River Laboratory into a permanent scientific observatory to assemble all of the scientific facts and to make a study of the various aspects of the problem of flood control;

*Resolved*, that it commends the efforts of General Brown and his colleagues of the Corps of Army Engineers in establishing the present laboratory;

*Resolved*, that it recommends to the Congress of the United States adequate and liberal support for the maintenance of this observatory;

*Resolved*, that the Association proffer its services to General Brown and his associates in this connection;

*Resolved*, that a copy of this resolution be furnished to the press, that a copy be spread on the minutes of this meeting, and that a copy be forwarded to General Brown and his associates.

3. *International Geological Congress*

*Moved*, that the American Association of Petroleum Geologists accept the invitation of the Organization Committee for the 16th International Geological Congress to edit and publish the proposed monograph dealing with the petroleum resources of the world and offer it for sale to members of the Congress and others at a price sufficient to eventually return to the Association the cost of publication, and

*Moved*, that it authorize the executive committee of the Association to make necessary arrangements with the Organization Committee of the Congress to carry this program into effect.

*4. Publication Fund*

*Moved*, that the executive committee take such steps as in its judgment are desirable to encourage groups or the membership at large to make contributions to the revolving publication fund, increasing the fund to $10,000.00.

*5. Oil in igneous rocks*

*Moved*, that the 1931 annual meeting of the Association concentrate attention on the occurrence of oil in igneous rocks.

*6. Stratigraphic sections*

*Moved*, that the executive committee grant the sum of $60.00, more or less, for the purpose of copyrighting in the name of the Association the stratigraphic sections in Oklahoma and adjacent states prepared by Levorsen's committee on the project, approved by the research committee, such grant later to be repaid from the sale of copies of the sections.

*7. Report of Research Committee to Business Committee on Financing of Research*

*Moved*, that the following report from the research committee be accepted and approved.

Under instructions from the research committee of the Association, the proposal to raise funds for financing certain research projects under supervision of the research committee is submitted for approval of the business committee. It is suggested that a committee be appointed by the president of the Association and be empowered to solicit in the name of the Association (1) contributions to a general research fund of $50,000.00, the income of which may be used for the promotion of research projects and activities specifically approved and supervised by the research committee; (2) research foundations in amounts of $5,000.00 and more, which shall carry the name of the donor, the revenue, or, with the approval of the executive committee of the Association and the consent of the donor, the principal of which shall be employed for the promotion of research projects specifically approved and supervised by the research committee; publication of the results of such researches to be controlled by the Association and to carry acknowledgment of the name of the research foundation under which the investigations were done.

Research constitutes the foundation stone or the life-blood of scientific progress. The American Association of Petroleum Geologists should be the leader in all things which will promote research. The research committee has specifically considered and has approved several important research projects, the carrying out of which depends upon the raising of funds to defray expenses. There are many other projects that would yield definite results of value to petroleum geology. The research committee urges you to approve a motion to authorize the adequate financing of a research program under the auspices of the Association.

*Sub-Committee*, RAYMOND C. MOORE
F. B. PLUMMER

*8. El Paso joint meeting*

*Moved*, that the executive committee commend the West Texas Geological Society for the interest shown in joining with the American Mining Congress

and the American Institute of Mining and Metallurgical Engineers in the proposed fall meeting at El Paso.

9. *Report of Constitution committee*

*Moved*, that the following amended constitution and by-laws, as proposed by the constitution committee, and as further amended by the business committee, be approved, and, subject to approval of legality by counsel, be submitted by letter ballot to the active members of the Association.

## CONSTITUTION AND BY-LAWS

(Adopted 1918 and amended 1921, 1923, 1925, 1927, 1928, 1929, and 1930)

### CONSTITUTION

#### ARTICLE I. NAME

This Association shall be called "The American Association of Petroleum Geologists," incorporated under the laws of Colorado the 21st day of April, 1924, for a period of twenty (20) years.

#### ARTICLE II. OBJECT

The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and improvements in the methods of winning these materials from the earth; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous persons posing as petroleum geologists.

#### ARTICLE III. MEMBERSHIP

*Members*

SECTION 1. Any person engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, or in sciences fundamental to petroleum geology, and in addition has had the equivalent of three years' experience in petroleum geology or in the application of these other sciences to petroleum geology or to research in petroleum geology or technology; and provided further that in the case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude teachers and research workers in recognized institutions whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

Active members alone shall be known as members.

*Life Members*

SECTION 2. The executive committee may grant life membership to members who have paid their dues and are otherwise qualified.

*Associates*

SECTION 3. Any person having completed as much as thirty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, is eligible to associate membership, provided at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in petroleum geology; and any person who is a graduate of an institution of collegiate standing in which he has done his major work in sciences fundamental to petroleum geology or petroleum technology, and who has the equivalent of one year's experience in the application of his science to the study of petroleum geology, shall be eligible to associate membership, provided at the time of his application for membership he shall be engaged in investigations in the broader subject of petroleum geology and technology.

Associate members shall be known as associates.

Associates shall enjoy all the privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Association in professional cards or professional reports or otherwise.

*Election to Membership*

SECTION 4. Every candidate for admission as a member or associate shall submit a formal application signed by him and endorsed by not less than three members, stating his training and experience and such other facts as the executive committee shall from time to time prescribe. The executive committee shall publish the names of such applicant and his sponsors at least once in the Bulletin.

Election to membership in any class shall be by, and solely at the discretion of, the executive committee; and except where unanimous action is herein required, the affirmative vote of a majority of this committee shall be sufficient for election.

SECTION 5. An applicant for membership, on being notified of his election in writing, shall pay full membership dues for the current year and on making such payment shall be entitled to receive the entire Bulletin for that year. Unless payment of dues is made within thirty (30) days by those living within the continental United States and within ninety (90) days by those living elsewhere, after notice of election has been mailed, the executive committee may rescind the election of the applicant. Upon payment of dues, each applicant for membership shall be furnished with a membership card for the current year, and until such written notice and card are received, he shall in no way be considered a member of the Association.

*Honorary Members*

SECTION 6. The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary members shall not be required to pay dues.

ARTICLE IV. EXECUTIVE COMMITTEE—MEETINGS AND DUTIES

*Executive Committee*

SECTION 1. The executive committee shall consist of the president, past president, and first, second, and third vice-presidents.

*Meetings and Duties*

SECTION 2. The executive committee shall meet immediately preceding the annual meeting and at the call of the president may hold meetings when and where thought advisable, to conduct the affairs of the Association. A joint meeting of the outgoing and incoming executive committees shall be held immediately after the close of the annual business meeting. Members of the executive committee may vote by proxy on matters which require a unanimous vote.

SECTION 3. The executive committee shall consider all nominations for membership and pass on the qualifications of the applicants; shall have control and management of the affairs and funds of the Association; shall determine the manner of publication and pass on the material presented for publication; and shall designate the place of the annual meeting. They are empowered to establish a business headquarters for the Association, and to employ such persons as are needed to conduct the business of the Association. They are empowered to accept, create, and maintain special funds for publication, research, and other purposes. They are empowered to make investments of both general and special funds of the Association. Trust funds may be created giving to the trustees appointed for such purpose such discretion as to investments as seems desirable to the executive committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice.

ARTICLE V. OFFICERS AND THEIR DUTIES

*Officers*

SECTION 1. The officers of the Association shall consist of a president, a first vice-president, a second vice-president in charge of secretarial and financial affairs, and a third vice-president in charge of editorial work. These, together with the retiring past president, shall constitute the executive committee and managers of the Association.

SECTION 2. The officers shall be elected annually from the Association at large by written ballot deposited in a locked ballot box by those active members, present at the annual meeting, who have paid their current dues and are otherwise qualified under the constitution. Each candidate, when voted for as a candidate for the particular office which he seeks, shall be thereby

automatically voted for as a candidate for the executive committee for one year, except that candidates for the presidency shall be automatically voted for as candidates for the executive committee for two years.

SECTION 3. No one shall hold the office of president for two consecutive years.

*Duties of Officers*

SECTION 4. The president shall be the presiding officer at all meetings of the Association, shall take cognizance of the acts of the Association and of its officers, shall appoint such committees as are required for the purposes of the Association, and shall delegate members to represent the Association. He may, at his option, serve on, and may be chairman of, any committee.

SECTION 5. The first vice-president shall assume the office of president in case of a vacancy from any cause in that office and shall assume the duties of president in case of the absence or disability of the latter.

SECTION 6. The second vice-president shall assume the duties of president in case of the absence of both the president and first vice-president. He shall be ex-officio secretary and treasurer, and have charge of the financial affairs of the Association, and shall annually submit reports as such secretary and treasurer covering the fiscal year. He shall receive all funds of the Association, and, under the direction of the executive committee, shall disburse all funds of the Association. He shall cause an audit to be prepared annually by a public accountant at the expense of the Association. He shall give a bond, and shall cause to be bonded all employees to whom authority may be delegated to handle Association funds. The amount of such bonds shall be set by the executive committee and the expense shall be borne by the Association. The funds of the Association shall be disbursed by check as authorized by the executive committee.

SECTION 7. The third vice-president shall be in charge of editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the Bulletin and for special publications, and, with the approval of the executive committee, may accept or reject material offered for publication. He may appoint associate, regional, and special editors.

SECTION 8. The officers shall assume the duties of their respective offices immediately after the annual meeting in which they are elected.

ARTICLE VI. MEETINGS

The Association shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held in March at a time and place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting shall be read, Association business shall be transacted, scientific papers shall be read and discussed, and officers for the ensuing year shall be elected.

ARTICLE VII. AMENDMENTS

Amendments to this constitution may be proposed by a resolution of the executive committee, by a constitutional committee appointed by the presi-

dent, or in writing by any ten members of the Association. All such resolutions or proposals must be submitted at the annual meeting of the business committee of the Association as provided in the by-laws, and only the business committee shall make recommendations concerning proposed constitutional changes at the annual Association business meeting. If such recommendations by the business committee shall be favorably acted on at the annual Association business meeting, the second vice-president shall arrange for a ballot of the membership by mail within thirty days after said annual Association business meeting, and a majority vote of the ballots received shall be sufficient to amend, provided more than one-half of the members return ballots.

## By-Laws

### ARTICLE I. DUES

SECTION 1. The fiscal year of the Association shall correspond with the calendar year.

SECTION 2. The annual dues of members of the Association shall be fifteen dollars ($15.00). The annual dues of associates shall be ten dollars ($10.00). The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member or associate before January first of each year, stating the amount of the annual dues and the penalty and conditions for default in payment. Members or associates who shall fail to pay their annual dues by April first shall not receive copies of the April Bulletin or succeeding Bulletins until such arrears are met.

SECTION 3. On the payment of three hundred dollars ($300.00) any member in good standing shall be declared a life member and thereafter shall not be required to pay annual dues. The funds derived from this source shall be placed in a permanent investment, the income from which shall be devoted to the same purposes as the regular dues.

### ARTICLE II. RESIGNATION—SUSPENSION—EXPULSION

SECTION 1. All resignations from the Association shall be presented in writing. The resignation of members or associates shall be accepted by the executive committee, subject to the payment of all outstanding dues or obligations of the resigning member or associate.

SECTION 2. Any member or associate who is more than a year in arrears on his dues shall be suspended, and any member or associate more than two years in arrears shall be dropped from the Association, unless the time of payment is extended by a unanimous vote of the executive committee.

SECTION 3. Any person who has ceased to be a member or associate under Section 1 or 2 of this Article may be reinstated by a unanimous vote of the executive committee.

SECTION 4. Any member or associate who, after being granted a hearing by the executive committee, shall be found guilty of violation of the code of ethics of this Association or shall be found guilty of a violation of the established principles of professional ethics, may be suspended or expelled from the Association by a unanimous vote of the executive committee.

ARTICLE III. PUBLICATIONS

SECTION 1. The proceedings of the annual meeting and the papers presented at such meeting shall be published in the annual Association Bulletin or in such other form as the executive committee may decide best meets the needs of the membership of the Association.

SECTION 2. The payment of annual dues for any fiscal year entitles the member or associate to receive without further charge a copy of the Bulletin of the Association for that year.

SECTION 3. The executive committee may authorize the printing of special publications to be financed by the Association from its general, publication, or special funds and offered for sale to the membership at not less than the cost of publication and distribution.

ARTICLE IV. REGIONAL SECTIONS, TECHNICAL DIVISIONS, AND AFFILIATED SOCIETIES

SECTION 1. Regional sections of the Association may be established provided the members of such sections are members of the Association and shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular annual meeting, an affirmative vote of two-thirds of the members present and voting being necessary for the establishment of such a section; and provided that the Association may revoke the charter of any regional section by a vote of two-thirds of the members present and voting at a regular annual meeting.

SECTION 2. Technical divisions may be established, provided the members interested shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular meeting, an affirmative vote of two-thirds of the membership present and voting being necessary for the establishment of such a division; and provided that the Association may dissolve a division by an affirmative vote of two-thirds of the members present and voting at any annual meeting. A technical division may have its own officers and it may have its own constitution and by-laws provided that, in the opinion of the executive committee, these do not conflict with the constitution and by-laws of the Association. The executive committee shall be empowered to make arrangements with the officers of the division for the conduct of the business of the division. A division may admit to affiliate membership in the division specially qualified persons who are not eligible to membership in the Association.

SECTION 3. Subject to the affirmative vote of two-thirds of the membership present and voting at an annual meeting, and with legal advice, the executive committee may arrange conditions for the affiliation or merger with the Association of duly organized groups or societies, which by object, aims, constitution, by-laws, or practice are developing the study of petroleum geology or technology.

ARTICLE V. DISTRICT REPRESENTATIVES

SECTION 1. The executive committee shall cause to be elected district representatives from districts which it shall define by a local geographic group-

ing of the membership. Such districts shall be redesignated and redefined by the executive committee as often as seems advisable. Each district shall be entitled to one representative for every seventy-five members, but this shall not deprive any designated district of at least one representative. The representatives so apportioned shall be chosen from the membership of the district by a written ballot arranged by the executive committee. They shall hold office for two years, their term of office expiring at the close of the annual meeting.

ARTICLE VI. BUSINESS COMMITTEE

SECTION 1. There shall be a business committee to act as a council and advisory board to the executive committee and the Association. This committee shall consist of the executive committee, not more than five members at large appointed by the president, two members elected by and from each technical division, and the district representatives. The president shall also appoint a chairman who need not be one of those otherwise constituting the business committee. The second vice-president shall act as secretary of the business committee. If a district or technical representative is unable to be present at any meeting of the committee he may designate an alternate, who, in the case of a district representative, may or may not be a resident of the district he is asked to represent, and the alternate, on presentation of such a designation in writing, shall have the same powers and privileges as a regularly chosen representative. The business committee shall meet the day before the annual meeting at which time all proposed changes in the constitution or by-laws shall be considered, all old and new business shall be discussed, and recommendations shall be voted for presentation at the annual meeting.

ARTICLE VII. AMENDMENTS

These by-laws may be amended by vote of three-fourths of the members present and voting at any annual meeting, provided that such changes shall have been recommended to the meeting by the business committee.

*Constitution committee*, MAX W. BALL, *chairman*
C. R. MCCOLLOM, *vice-chairman*
D. C. BARTON
R. C. COFFIN
ANTHONY FOLGER
SIDNEY POWERS
G. R. STEVENS

*10. Qualifications of geophysicists and paleontologists*

*Whereas*, after careful study of the question and after consultation with many members of the Association, the executive committee of 1929 were unanimously of the opinion that Article III of the constitution, regarding qualifications for membership, permits a liberal interpretation which would justify admission of properly qualified and experienced geophysicists and paleontologists to membership in the Association provided they are engaged in petroleum geology in its broader meaning; and

*Whereas*, after careful study of the question, the present executive committee is unanimously of the opinion that properly qualified and experienced

geophysicists and paleontologists engaged in the search for petroleum should be admitted to membership in the Association, although this committee is divided in its opinion as to whether a rewording of this article in the constitution would not be better than a liberal interpretation of the requirements as at present defined,

*Be it resolved,*

(1) That, until Article III of the constitution be written so that it shall more clearly cover the case of the geophysicists and paleontologists, a liberal interpretation be placed on this article in reference to the admission of properly qualified and experienced geophysicists and paleontologists to membership in the Association, and

(2) That the Association hereby extends to the geophysicists and paleontologists engaged in petroleum geology an invitation to join the Association on terms and with rights and privileges equal to those of geologists of the same rank.

*Business committee*, WALLACE E. PRATT, *chairman*
A. R. DENISON, *secretary*

| | | | |
|---|---|---|---|
| D. C. BARTON | R. E. DICKERSON | THEO. A. LINK | L. C. SNIDER[5] |
| S. P. BORDEN | A. W. DUSTON | C. R. MCCOLLOM | J. Y. SNYDER |
| J. P. BOWEN[1] | H. B. FUQUA | R. S. MCFARLAND | R. E. SOMERS |
| M. G. CHENEY | S. A. GROGAN | F. A. MORGAN, JR. | WILLIS STORM |
| GLENN C. CLARK | R. F. IMBT | H. J. PACKARD[3] | A. C. TROWBRIDGE |
| VICTOR COTNER[2] | F. H. LAHEE | SIDNEY POWERS | J. M. VETTER |
| E. F. DAVIS | MARVIN LEE | J. B. REESIDE[4] | L. H. WHITE |
| A. DEUSSEN | A. I. LEVORSEN | CHAS. H. ROW | W. E. WRATHER |

*Maracaibo Section*

Upon recommendation by the executive committee it was

*Moved*, that the petition of the Maracaibo Geological Association to be made a regional section of the A. A. P. G. be approved, and that the executive committee officially charter the Maracaibo Section of the Association.

The motion carried unanimously.

*Paleontology and Mineralogy Section (Division)*

Upon recommendation by the executive committee it was

*Moved*, that the petition of the Society of Economic Geologists and Mineralogists to be made a technical section (division) of the A. A. P. G. be approved and that the executive committee officially charter the Section (Division) of Paleontology and Mineralogy.

The motion carried unanimously.

[1]Bowen represented C. W. Clark.

[2]Cotner represented H. E. Crum *vice* Max Bauer resigned.

[3]Packard represented C. M. Rath and H. A. Stewart.

[4]Reeside represented H. D. Miser.

[5]Snider represented H. J. Wasson.

*Methods of election*

Mr. Gardner offered the following motion.

*Moved*,

(1) That the question of method of election of officers, which was tabled at the last annual meeting for a period of two years, be taken from the table and reopened for study during the coming year; and

(2) That a committee of seven be selected by the executive committee and appointed by the president within the next sixty days, for the purpose of thoroughly canvassing the methods of election of officers; carefully studying these methods; drawing up suggestions for the proper method of election of officers of the Association; submitting these suggestions to the business representatives and local geological societies for their recommendations; and finally, after receiving expressions of opinion from the membership through this means,

(3) That the committee draft such changes in the methods of election of officers as may seem desirable and submit the same to the business committee of 1931 for their recommendation.

After some discussion the motion carried, with 3 or 4 opposed.

The meeting was adjourned at 11:20 A. M.

A. R. DENISON,
*Second vice-president*

# Memorial

## IRVING V. AUGUR

Irving Augur died in Ojai, California, on February 17, 1930, at the age of 43. He had been in poor health for two years previously, and had only recently moved to Ojai and planned to give up active work on account of his health. Like so many other Americans, the call of the strenuous life was so strong with him that he did not accept the warnings of impending trouble until it was too late. A visit by the writer a few days before his death found him busy with plans for the future; a typical American in his desire for accomplishment.

Irving Augur was born in Iowa and came with his family to Los Angeles when of high school age. He graduated from the Los Angeles High School, and attended the University of Southern California, where he was a member of the Theta Psi fraternity. He later attended the University of California at Berkeley, from which he graduated in 1910, having majored in geology. He belonged to the Phi Kappa Sigma fraternity, and was prominent in music and dramatics, taking part in several college operas, and singing the leading part in his class Senior Extravaganza.

After graduation he followed the oil business as geologist, petroleum engineer, and company executive. He became well known as a deputy oil and gas supervisor for the California State Mining Bureau, in which capacity he served from 1917 to 1920. At the time of his resignation from the Mining Bureau he was in charge of the Los Angeles office, and had contributed several useful articles on petroleum engineering in the fields in which he had been stationed.

In 1920 he became one of the organizers of the Bolsa Chico Oil Company, and was successively its treasurer, vice-president, and president, becoming president in 1926. The progress of the company from a start with one well at Huntington Beach to its present standing was largely due to his efforts and ability. This was his crowning accomplishment, and by it he will be remembered in the oil business.

By his many friends he will be remembered for his friendly and affable nature, and his talents in connection with social entertainments. It was along this line that he was especially active in The American Association of Petroleum Geologists. For the 1926 meeting in Los Angeles he arranged the dinner and dance at the Flintridge Country Club, and again in 1928 he arranged the dinner in the Mack Sennet Studio, which will be long remembered by all those who were fortunate enough to attend. He was never happier than when following his avocation of entertainer and purveyor of good times to his friends.

He was married in 1916 to Dora Rogers, daughter of an old Los Angeles family, and a sweetheart of his high school days. The congenial atmosphere

of his home gave him rest and strength for his very strenuous business life. One son, Irving Junior, is now six years of age.

He is survived by his parents, Edmund F. and Ella Augur, two sisters and a brother, besides his wife and son.

WALTER A. ENGLISH

LOS ANGELES, CALIFORNIA
March, 1930

# AT HOME AND ABROAD

## EMPLOYMENT

The Association maintains an employment service at headquarters under the supervision of J. P. D. Hull, Business Manager.

This service is available both to members who desire new positions and to companies and others who desire Association members as employees. All requests and information are handled confidentially and gratuitously.

To make this service of maximum value it is essential that members coöperate fully with Mr. Hull, especially concerning positions available to active and associate members.

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Officers of the San Antonio Section of the A. A. P. G. are: president, D. R. SEMMES, consulting geologist; vice-president, HERSCHEL H. COOPER, consulting geologist; and secretary-treasurer, ED. W. OWEN, L. H. Wentz-Oil Division, all located in the Milam Building, San Antonio, Texas.

C. D. AVERY and C. E. DOBBIN, of the conservation branch of the U. S. Geological Survey, Rocky Mountain division, are making a land classification of coal and oil lands in Louisiana, Mississippi, and Alabama.

ARTHUR L. HAWKINS, geologist for the past eight years with the Transcontinental Oil Company, has resigned and opened an office in the Continental Oil Building, Denver, Colorado, as consulting geologist.

H. W. C. PROMMEL, consulting geologist, of Denver, Colorado, has accepted a position as chief geologist in charge of non-ferrous minerals for the Soviet government of Russia. Mr. Prommel's home address is 731 South Downing Street, Denver, Colorado.

JAMES B. TEMPLETON has resigned from charge of the East Texas district of the Tidal Oil Company, Tyler, Texas, and is making a consulting trip to San Domingo for George Devendorf of New York City.

E. P. PHILBRICK, of Tulsa, has been transferred to the Wichita, Kansas, office of the Magnolia Petroleum Company as head of the geological department.

GEORGE R. STEVENS, in charge of the activities of the Simms Oil Company at Shreveport, Louisiana, has resigned to operate independently.

EDGAR KRAUS, geologist for the Atlantic Oil Producing Company at San Angelo, Texas, recently presented a paper on "Petroleum Geology as Practiced in West Texas," before the Bureau of Economic Geology of the University of Texas and the Southwestern Geological Society at Austin, Texas.

E. DEGOLYER has been appointed by president SIDNEY POWERS as chairman of the A. A. P. G. general business committee and ALEXANDER DEUSSEN has been appointed vice-chairman. ALEX W. MCCOY and D. C. BARTON are members-at-large.

HOWARD SAMUELL has been elected vice-president and geologist for the Empress Oil and Gas Corporation, with Texas offices at San Antonio and Coleman.

HENRY S. WASHINGTON, in the first issue of the *Journal of the Maryland Academy of Sciences*, calls attention to the fact that the ridge in the middle of the South Atlantic midway between Africa and South America and known as St. Paul's Rocks is composed of metamorphic rocks. This militates against the Wegener hypothesis of the westward drift of the American continents.

A. J. BAUERNSCHMIDT, Jr., recently with the Sun Oil Company, has taken a position as paleontologist and geologist with The Union Sulphur Company and is now located at Sulphur, Louisiana.

PROFESSOR W. H. TWENHOFEL, of the department of geology at the University of Wisconsin, made a lecture tour of the southwest early in April to discuss the origin and constitution of limestone and related rocks and the influence of climate and topography on sedimentation. He spoke at Wichita, April 7; at Oklahoma City, April 8; at Tulsa, April 9; at Fort Worth, April 10, and at San Angelo, April 12, under the auspices of the geological societies of these cities.

DONALD C. BARTON is president, E. E. ROSAIRE is vice-president, and JOHN F. WEINZIERL is secretary, of the newly organized Society of Economic Geophysicists, with headquarters at Houston, Texas.

H. NORTON JOHNSON, geologist for the General Petroleum Corporation, Los Angeles, published "California Oil Production Outlook for 1930" in *Mining and Metallurgy* for April, 1930.

W. C. SPOONER, consulting geologist, of Shreveport, Louisiana, has moved his office to the Slattery Building.

STANLEY C. HEROLD, consulting geologist at Los Angeles, California, and umpire at Kettleman Hills, read a paper before the March American Petroleum Institute meeting in Los Angeles entitled "Problem of Drainage at Kettleman Hills." It was published in the *Oil and Gas Journal* (March 27, 1930).

JOSEPHINE E. TILDEN, professor in the University of Minnesota, has proved that the red color of Mesozoic and Paleozoic red rock salt is due in large part to the presence of ferrous iron oxide, although chromogenic bacteria are the source of the red color in modern brines and in salt made from these brines. The rock salt contains fossil filamentous blue-green algae. See "A Phycological Examination of Fossil Red Salt from Three Localities in the Southern States," *Amer. Jour. Sci.* (5), Vol. 19 (1930), pp. 297-304.

Jun-ichi Takahashi and Tsugio Yagi, of Tohoku Imperial University, Sendai, Japan, in a paper entitled "The Peculiar Mud-Grains in the Recent

Littoral and Estuarine Deposits, with Special Reference to the Origin of Glauconite," *Annual Report of the Work of Saito Ho-on Kai*, No. 5 (Sendai, December, 1929), call attention to the coprolitic origin of mud-grains which may or may not contain glauconite.

JOHN M. LOVEJOY, president of the Petroleum Bond and Share Company of New York City, spent April in Europe on a business trip.

A. W. AMBROSE, manager of the oil production division and of the geological and land departments of the Empire Gas and Fuel Company, at Bartlesville, Oklahoma, has been elected a vice-president of the company.

CHARLES M. COATS, formerly of El Dorado, Arkansas, is now engaged in the oil business of Wichita, Kansas.

DAVID P. DEAN, geologist for the Barnsdall Oil Company, has been transferred to Jackson, Mississippi.

C. A. MCADAMS, of Wichita, Kansas, has resigned from the White Eagle Oil and Refining Company.

IRWIN HUGHES and W. J. NOLTE, of Wichita Falls, Texas, are engaged in consulting practice.

H. W. MCCLELLAN is in charge of geological work for the Burke-Greis Oil Company at Tulsa.

B. S. RIDGEWAY, in charge of geological work for the Roth and Faurot Oil and Gas Company, left their employ, April 15, to go into consulting work for himself, with headquarters at Independence, Kansas.

E. F. ESTERGREN has resigned as geologist for The L. G. Bradstreet Company, and intends to go into consulting work. His address is, 1011 Sixth Avenue, Fort Worth, Texas.

# PROFESSIONAL DIRECTORY

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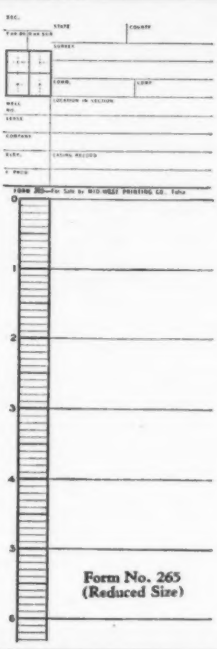

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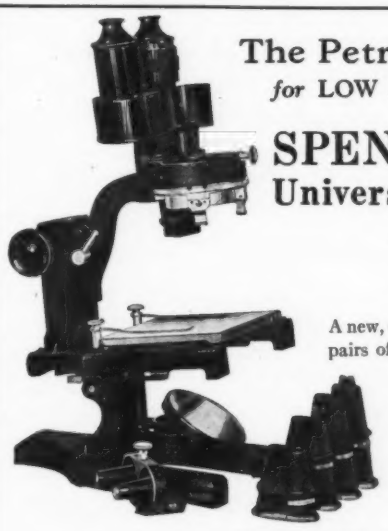

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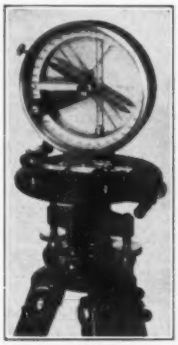

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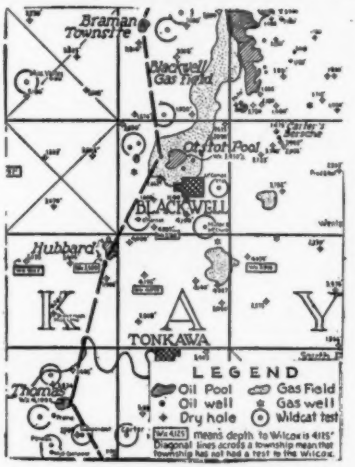


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